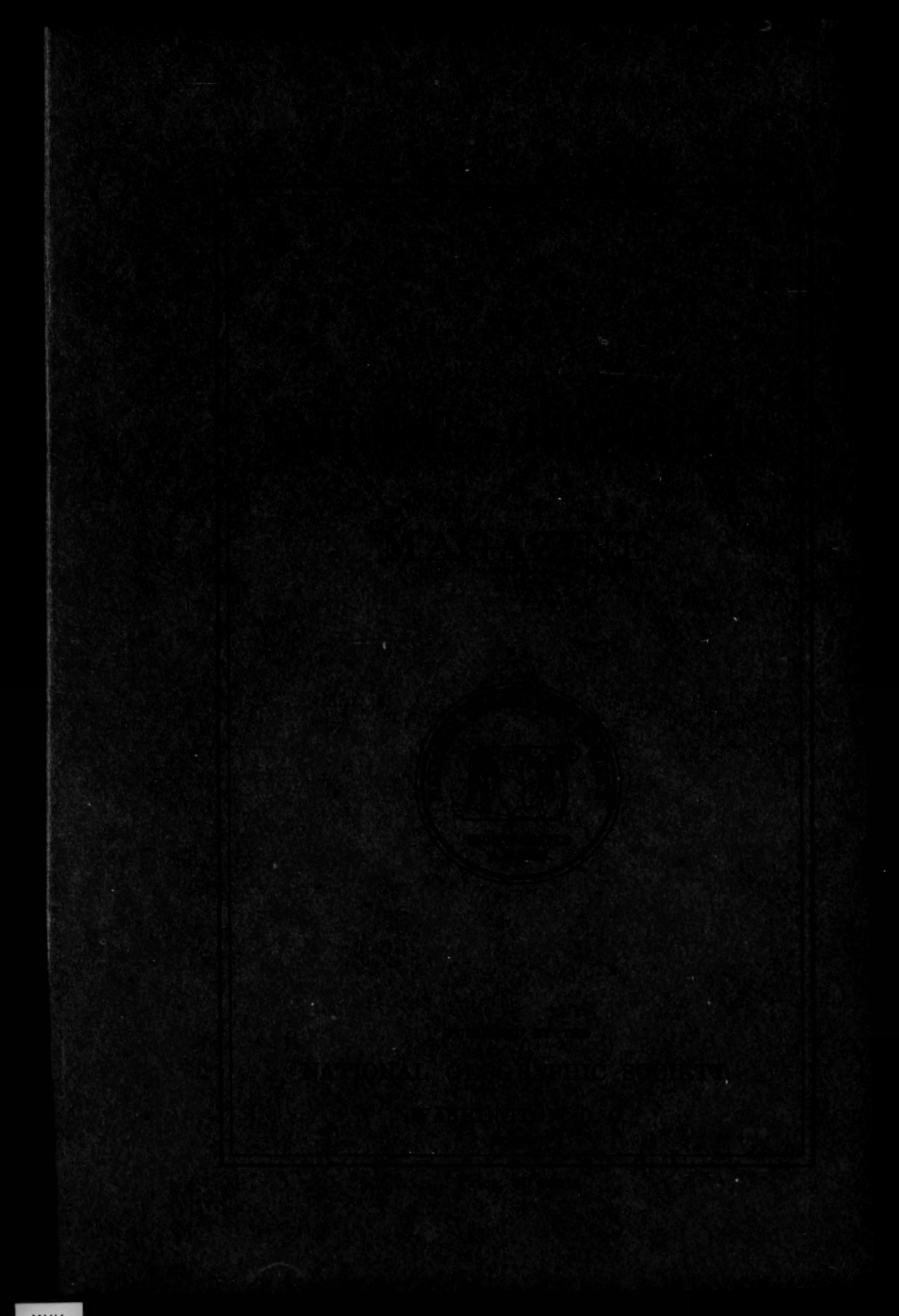

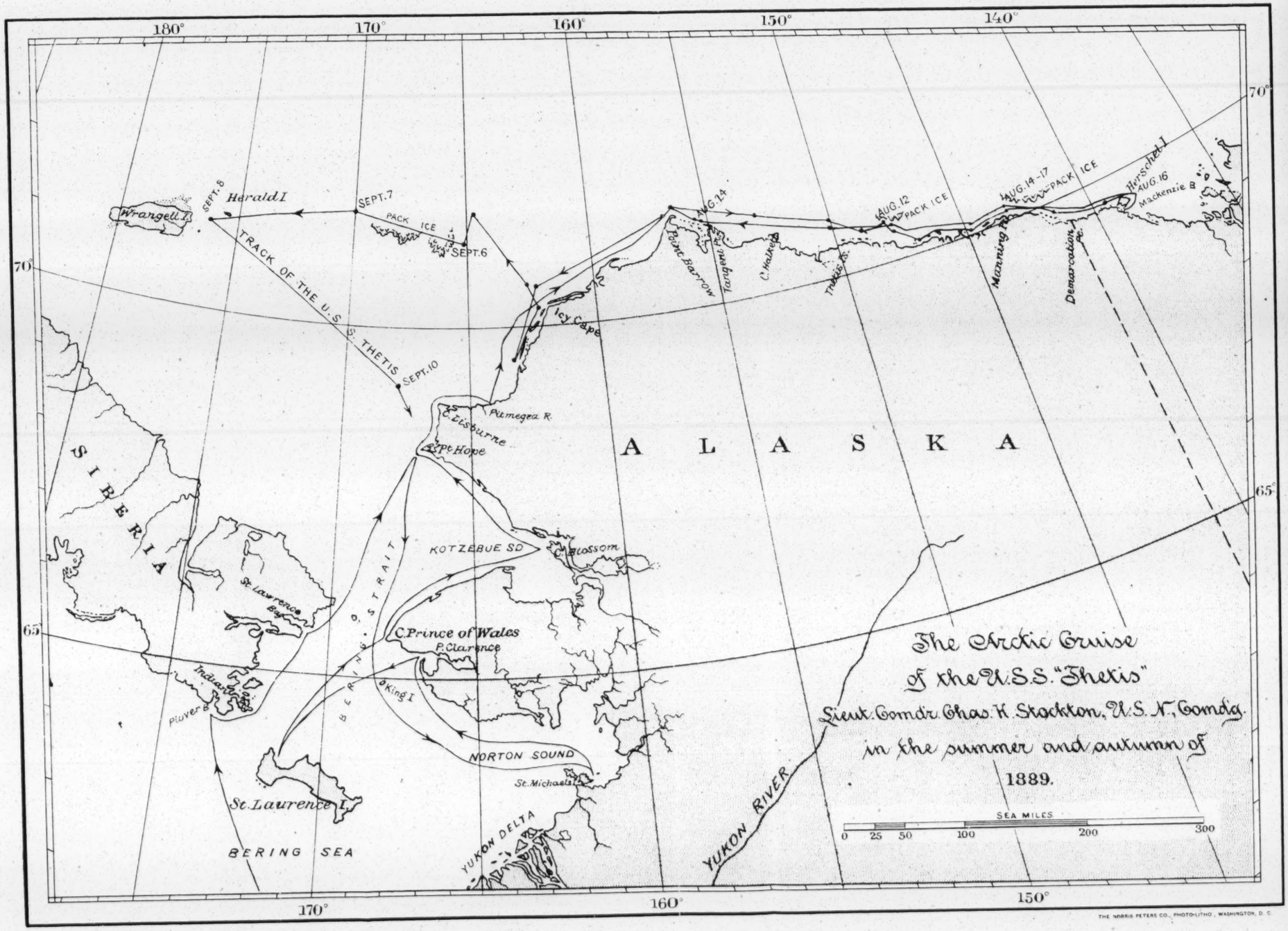

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THE ARCTIC CRUISE OF THE U. S. S. THETIS IN THE SUMMER AND AUTUMN OF 1889.

By Charles H. Stockton.

A German writer of note once said, in the course of a discussion upon certain French characteristics, that "the trouble with the French people is,—they do not *know* Geography."

Whether this is still true of the French, as a nation, or whether the authority may be considered a good one, it is not pertinent for me here to say ; but I feel that of the nations of the world, this country, above all others (England, perhaps, alone excepted), should not have the want of knowledge of geography classed among its national failings.

We have, however, very much geography yet to learn, as individuals and as a nation ; not only of countries beyond our own but particularly of our own continent and our own domain, while commercial geography is almost an unknown and forbidden study.

Professional geographer as I am, as member of the naval service, I find that every cruise adds to my geographic knowledge, and in giving an account of the cruise during last summer of the ship which I had the honor to command, I trust that I may be enabled to present some geographic facts as interesting to my

fellow-members of the Geographic Society as they were novel and instructive to myself.

Before beginning my narrative, however, let me give you an idea of the extent of the shore-line of the territory or semi-colonial province along which so much of our cruise was made.

Alaska has an area of about 580,000 square miles, consisting of a large mainland with a coast-line 6,650 miles in length, and also of more than 1,100 islands, with a coast-line of 2,950 miles, the entire coast-line being 9,600 miles. The coast-line of the rest of the United States, including islands, is only 6,580 miles, thus making the coast-line of Alaska 3,020 miles more than the coast-line of all of the rest of the United States.

Of this great country the part known best and visited annually by tourists is that insignificant portion of southeastern Alaska which consists of the Alexander archipelago and its neighboring main coast-line, differing in its scenery, topography, climate, and native inhabitants, from the greater part of this vast territory.

It is fortunate, however, that this corner of Alaska is so easily and comfortably reached by the summer traveler, as, with the exception of the coast-line and inlets between Sitka and Kodiak, which includes the Fairweather ground and the St. Elias range of mountains, this portion contains perhaps the finest and most striking scenery and the largest and grandest glaciers in the territory, if not in all North and South America.

The U. S. S. Thetis was assigned in 1889 to the duty of looking out for the commercial and whaling interests of the United States in Bering sea and the Arctic ocean, to which was subsequently added the duty of assisting in the establishment and erection of a house of refuge in the vicinity of Point Barrow, the most northerly point of our Arctic possessions. The duty assigned to the Thetis did not include the protection of the sealing interests of the United States, nor of those interests enjoyed by the Alaska Commercial Company as the regular lessees from the United States of the Pribyloff group of islands. This was confided to the Revenue Marine Service of the Treasury Department.

The Thetis left San Francisco on the 20th of April, 1889, and after a detention of a month at Tacoma, upon the placid waters of Puget sound, awaiting supplementary orders, reached Port Tongass, in extreme southeastern Alaska, on the 31st of May, and Sitka, the territorial capitol, upon the 2d of June. After a stay

of six days at the latter place the vessel left for the island of Ounalaska, one of the Aleutian chain, which was safely reached, after a stormy passage, early on the morning of the 17th of June.

The revenue-steamer Richard Rush, commanded by Captain Shepherd, was found at anchor at this place, having arrived a few hours before the Thetis; she had entered upon the duty of patrolling Bering sea, between Ounalaska and the Pribyloff group, for the protection of the sealing interests. The seals approach the hauling-out grounds and breeding places upon the islands of St. Paul and St. George in lanes, as it were, from the Pacific, reaching Bering sea by means of the various passages between the Aleutian islands, and converging as they approach the Seal islands, the position of which seems so well known to them. The "marauders," as the men on the sealing schooners are called who hunt them on their way north, shoot them from small boats, killing the many in order to procure the few.

Ounalaska, or rather the village and harbor of Iliuliuk, upon the island of Ounalaska, is the principal and most frequented harbor in the Aleutian islands, and from its position is a most convenient port for coaling, watering and provisioning en route to the Seal islands, St. Michaels (at the mouth of the Yukon river), the anchorages in and near Bering strait, and the Arctic ocean. This harbor is the headquarters of all of the districts of the Alaska Commercial Company, and is the principal coaling and distributing station and rendezvous of their vessels in Alaska. The company here affords facilities in the way of buoyage, wharfage, etc., which are not only useful to their own vessels but of great service to government and other vessels whose duty or interests call them to these waters.

The revenue steamer Bear was to be met by us at Ounalaska, in order that we could take from her any portion of the stores and material to be used in the constructing and provisioning of the house of refuge at Point Barrow that her commanding officer desired to transfer to us.

While awaiting the arrival of the Bear, the Thetis was watered and coaled and prepared for the northerly trip before her. An opportunity offered me by the delay was availed of to inspect the store-houses of the Alaska Commercial Company at this point. The most interesting of the store-houses was that containing the skins and furs collected in the various parts of the

district of which this place was the dépôt. The finest of the furs was that of the sea-otter, probably the most valuable fur in the world, a very superior skin of that animal having been sold at the great fur market in London for £170. Such otters are found in the vicinity of Ounalaska and the outlying rocks and islands as far east as Kodiak, and are becoming more and more difficult to obtain, causing greater risk and hardships every year to the Aleuts, who hunt these animals as a principal means of livelihood.

Besides the otters the store-house held the furs of the beautiful silver-gray fox, and those of the blue, the cross, and the snowy white Arctic fox. There were also black and brown bear skins, beaver, and fur-seal, the latter, though the greatest and most profitable source of revenue to the Company, being by no manner of means among the more valuable of the raw furs.

To exchange for furs collected, either directly by natives or by independent traders, the Alaska Commercial Company has a large assortment of stores, provisions, and goods, worthy of a large country-store, or a Macy's in miniature, which are sold to the natives for money or in exchange for the furs they bring to the company. And just here can be seen the commercial aspects of civilization: as the natives become used to the luxuries and comforts of a civilized and semi-civilized state of life, their wants and their purchases increase and the securing of one otter-skin will not, as in times past, satisfy their wants or the requirements of their wives and families. Hence they become both greater producers and consumers, more otters are hunted for, and the Company is the gainer.

The houses in which the Aleuts and Creoles reside at Ounalaska were found to be well built of frame, sufficiently large and fairly clean. The old houses of earth and sod standing near by show the great improvement that has been made of late years in the method of living.

Upon the 22d of June the Revenue Steamer Bear came in to the anchorage, and the Thetis and the Bear, once companion ships in the Greely Relief Expedition, met again in the far north.

Upon conference with the commanding officer of the Bear, Captain M. A. Healy, it was found that he did not consider it desirable to break the bulk of his cargo and share the stores for the refuge-station with us; hence, being free to pursue our course, we left on the 24th of June for the island of St. Paul, one of the Seal (or Pribyloff) islands.

We arrived at these islands on the evening of the 25th of June, after groping around in the heavy and almost constant fog and mist that envelop them. During our short stay at St. Paul we were able to see a drive of seals from a rookery and the killing, skinning, and packing, which followed; but what we found to be the most interesting was the visit to the rookeries, both from the inshore side and from boats along the sea front. The systematic partition of the grounds, the formation of the harems, the exclusion of the young males, and the aggressive conduct of the older ones, all proved most interesting and novel. This, however, has been described so often that I will not here repeat it.

Leaving these islands, so unlike any others in the world, we proceeded to the north and west to St. Mathew Island, a large and uninhabited island in the middle of Bering sea. The object in visiting this island was twofold, the first being to ascertain if there were any shipwrecked persons upon the island, the other being to verify the statement made upon the chart we possessed that the island was infested with polar bears. Upon our arrival and landing upon the island we found plenty of old tracks but no recent evidences of the existence of polar bears. This was ascertained after honest and fatiguing endeavor to find them by parties of officers and men from the ship, who scoured the eastern part of the island, both upon the hills and upon the low tundra, but without success.

St. Mathew island is probably the southern limit of the solid ice in winter in this part of Bering sea, the ice below it to the southward and toward the Aleutian chain being made up of newer ice and detached floes of well broken ice. It is surrounded by the ice during seven months of the year, and generally enveloped with fog during the remaining five months. Winds and rains sweep over it during the summer, the low land being composed of wet, grassy tundra, while the higher elevations are formed of scoriæ and volcanic rock.

A large quantity of drift-wood found piled up upon the steep shingle beaches probably came down the Yukon river from the interior of Alaska, there being no growth of trees upon this desolate land.

After leaving St. Mathew island we stood over to the Siberian side of Bering sea, in order to ascertain the whereabouts of the whaling fleet, and, if possible, to gather some news concerning the fate of the whaling bark "Little Ohio," a vessel that had been missing since the previous autumn.

Plover bay, Cape Tchaplin and St. Lawrence bay, upon the Siberian side, were all visited in turn, but without success, and I then determined to pass through Bering strait and enter the Arctic ocean. This was done upon the 3d of July, after a heavy snow-storm in the morning, followed, later in the day, by a fog so dense that we passed through the straits without seeing land on either side, or the Diomede islands, in the middle.

Entering the Arctic we pushed on toward Point Hope, to the northward of which the "Little Ohio" had last been seen. On the morning of the 4th of July the land about Point Hope was sighted and soon afterwards we met our first ice, coming out in floes from Kotzebue sound, stretching some distance from the shore and slowly moving to the northward and westward with the current.

Skirting along this ice with the hope of getting around it to the northward of Point Hope, without success, we entered it, and after working through it for several miles with considerable difficulty we finally cleared it and came to anchor off the native village at Point Hope, finding there two whalers who had just preceded us, and obtaining the news that the bark "Little Ohio" had been wrecked directly opposite the point where we were then at anchor. Taking on board, the next day, those survivors of this shipwreck who still remained at this place, we left for St. Michaels, near the mouth of the Yukon river, there to transfer the survivors to the steamer of the Alaska Commercial Company, and to send the news of this sad disaster to the Navy Department and to the world. In passing through the ice outside of Point Hope the first polar bear of the season was sighted, posing upon a high floe of ice. A few shots settled his case and his body was fortunately secured, his skin now forming one of the trophies of the cruise.

On our way back through Bering strait we found the vexatious combination (to be met with again and again in the cruise) of a heavy fog, much drift ice, and an opposing current.

Reaching St. Michaels we found there two steamers of the Alaska Commercial Company at anchor, besides several river-steamers, and a summer rendezvous of natives from the coast, miners from the interior, and traders and missionaries from the Yukon,—all here to meet their annual mails and supplies. In addition there was a party of government surveyors to determine the boundary-line, an account of whose early journey has been

given to the Society by Mr. Russell. There were seventy-three tents, by actual count, pitched about St. Michaels at the time of our stay, the abodes of these temporary residents.

St. Michaels is the most northerly settlement and trading post of the Alaska Commercial Company. It is the outlet of the Yukon river trade and also the source of supplies for the country bordering upon the Yukon and its many tributaries, reaching in this way a portion of the Northwest Territory of the Dominion of Canada, west of the Rocky Mountains.

In the winter-time the post consists of the offices and storehouses of the Alaska Commercial Company, with a few residences for their white employees, and a small native village.

Small, light-draught, stern-wheel steamers ascend the Yukon and its tributaries for a distance of 1,700 miles, reaching the mouth of that river in part by an inside channel and in part by sixty miles of outside coasting.

After a short stay at St. Michaels we proceeded to Port Clarence, where a large number of the whaling fleet were met, consisting of seven steam-whalers, six sailing whalers, one trading vessel, and a sailing tender. From the tender these vessels receive coal provisions, and supplies, sending back to San Francisco the oil and whale-bone of the spring catch.

Port Clarence is the best, as it is the last, harbor on the American side before reaching the Arctic, where no harbors exist worthy of the name, west of Herschel island. There is no native settlement of any size on the bay, but natives assemble here from the surrounding country and islands to trade with the whale-ships in summer.

Leaving Port Clarence we ran to the southward by King island to St. Lawrence island, in search of a sailing tender that was long over-due; returning, after a short stay off the village near Cape Prince of Wales, we again entered the Arctic ocean. As it was too early to go to Point Barrow we proceeded to Kotzebue sound and Hotham inlet. In the vicinity of the latter place, every year, a summer rendezvous of natives occurs for trading purposes, the Eskimos from the Diomedes and Cape Prince of Wales bringing articles of trade from Siberia, while the Eskimos from Point Hope bring articles obtained from the whalers; these Eskimos are met by the inland natives from the rivers that flow into Hotham inlet and Kotzebue sound, principally from the Kowak, the Noatak and Salawik rivers. The nearest available

anchorage we found was Cape Blossom, from which place we visited the rendezvous and were visited in turn by the natives. We had now been enjoying for some time twenty-fours hours of daylight, the midnight-sun having lighted our way to and from Point Hope during our first visit to that place.

Leaving Cape Blossom upon the 24th of July we stood out of Kotzebue sound for the northward, running the greater part of the time in a heavy fog. We passed Point Hope on the 25th, Cape Lisburne on the 26th, and anchored off Cape Sabine early in the morning of the 27th of July. Near by was a very wide vein of lignite coal, from which the Thetis had been coaled the previous year and to which the name of "Thetis coal mine" had been given. This had been worked during the present summer, also, and a party of natives who were encamped near by had furnished coal to some of the whalers.

Being now in the vicinity of a stream known to the natives as the Pitmegea, I went in a whaleboat to examine its mouth and entrance, as this stream was unknown to but few whites and did not exist upon any charts or maps. It was found to have but three feet of water on the bar at its entrance, but after crossing this a depth of six feet was found. The stream was found so full of bars and shoals that we could ascend but a short distance after entering it. The river and its narrow valley were very winding, the general course being northwest from its source to the coast. After the spring thaw, and the rains that follow, the stream rises to a depth sufficient for the natives to ascend and descend it with their light-draught skin-boats for a distance of about forty miles. Its length is estimated to be over one hundred miles. The river had been explored the previous year by John W. Kelly, who was this summer employed on board the Thetis as the official interpreter, and to him I am indebted for the following description of the ice-cliff existing upon the banks of the Pitmegea, and also of a peculiarly built stone hut near the source of one of the tributaries.

Ice-Cliff on the Pitmegea.

This ice-cliff is about twenty-five miles from the mouth of the Pitmegea, at a place where the hills run their spurs out to the banks of the river, closing the picturesque valley that stretches away to the sea-coast in an almost unbroken width of a mile. A glacier faces southward, and receives the full benefit of the sun-

light during the short polar summer. Gales have deposited particles of soil and débris of plants, along with their seeds, upon the surface of the ice to a depth of from four inches to a foot. The snow-fall of winter soon vanishes before the June sun, while the light covering above the glacier preserves it intact. Vegetation is warmed into life in a remarkably short time, and the brown coat left by the receding snow is almost miraculously transformed to a robe of green and studded here and there with bright polar flowers, there being buttercups, dandelions, yellow poppy, bright astragals, gentians, daffodils and marguerites. The latter are small and unobtrusive, making a showing in a modest way as if they wished to apologize to their sister flowers for their appearance among them. Like beautiful orphan girls, one cannot resist a compassionate tenderness of feeling toward them. But these innocent little flowers, chaste as the ice field upon which they grow, bloom in the polar garden with as much right as the glacier's gentian. Besides flowers, there are the hardy grasses whose roots penetrate the light covering of soil to the ice-bed, whence they derive their nourishment. A few Arctic willows are to be seen, but they only grow about a foot in length, and trail upon the ground. The Pitmegea river is gradually cutting into the glacier, receding from its opposite bank and leaving a bed of gravel behind. During the summer the ice melts away, leaving the protruding soil above it like the eaves of a house; when it protrudes too far for the strength of the grass roots, it topples over into the river. At the freezing in September, icicles freeze from the overhanging sod to the river ice below, forming a narrow portico four miles in extent.

Old Stone Hut.

On the highest peak at the source of Ikuk creek, a southerly tributary of the Pitmegea, are the ruins of a hut and smaller outhouse, the like of which has never been met with in Northwestern Alaska. Above the grass line, past perpetual beds of snow, up where wild storms sweep away ice, snow, and soil, where only a few gray lichens are to be seen, man, at some former time, has placed a habitation. On the crest of the mountain there is a ragged limestone comb twelve feet high, cracked and shattered into flakes by the vigor of the polar winters. On the south side of this comb, sheltered from the prevailing north winds, excavations have been made into the rock. Taking the comb of rock

for one side of the house, the other side of the semicircle has been built up with flat stones, laid up like bricks in masonry, but without mortar. Moss and soil have been in all probability used here instead of mortar, but years of fierce winds have blown it out from the crevices. The structure is conic in shape, after the manner of a Greenlander's snow-hut. This one is about seven feet in diameter. Facing its entrance is a smaller house of similar construction, most likely used as a shelter for game. Winter storms have crumbled away the roofs of both so that they have fallen in, and the fragments of stones are partially covered with soil. The whole bears the impression of age, and no natives have been found who have ever heard of it. From the summit of this peak a splendid view is obtained of the surrounding country, the Arctic ocean, and herds of passing reindeer.

Gold has been found near the Pitmegea, at the head of the same creek and tributary, it being contained in sulphurets of iron, which exist in large quantities in that vicinity, there being from $3.50 to $8.00 worth of gold in a ton; the country is all but impassable, however, and this, together with the shortness of the season, would prevent any mining with profit.

Our party returned from the Pitmegea with a few ptarmigan and ducks, a[illegible] upon our arrival the ship was at once gotten under way and we stood to the northward for Point Barrow. Drift-ice was constantly passed, but fortunately so scattered as not to form any obstruction to free navigation.

On the next day we enjoyed a superb Arctic summer's day, and began to fall in with the whaling fleet on the way north to Point Barrow. Fifteen vessels were sighted and passed, most of them vessels under sail. Rounding the dangerous Blossom shoals and the Icy cape of Captain Cook, we stood to the northeast, finding generally clear water, with scattered drift-ice. Upon the floes we found great quantities of walrus, in some cases stretched at full length, sound asleep. One huge fellow remained so undisturbed at our approach that he was supposed to be dead, but a well aimed Irish potato aroused him so r[illegible]ely that he quickly slid off the floe and disappeared beneath the water.

Pushing on we passed Pt. Belcher at 9.30 in the evening, in the fog and rain, and came to heavy masses of ice over which a low fog had settled. With some delay and difficulty we worked out of both the fog and the ice and at five o'clock in the morning

sighted four vessels—steamers—at anchor off the village of Ootkavie at Cape Smyth, 8 miles from Point Barrow, and the site of Captain Ray's Signal Service meteorologic station of some years ago, the house that sheltered the party being still standing. One of the steamers proved to be our old friend the "Bear," which had passed to the northward when we had returned southward from the Arctic with the survivors of the "Little Ohio." The other vessels were made out to be steam-whalers, and at seven o'clock we anchored near them, off the site determined upon for the house of refuge.

Finding the Bear had commenced to discharge her stores and materials, all of our facilities were at once used in tending her assistance, our steam launch Achilles (now, as of yore, the child of the Thetis) being busily at work towing boats to and fro, while our men and mechanics, with officers, were busily engaged in aiding the construction of the house of refuge.

Our arrival at Cape Smyth and vicinity of Point Barrow was on the 29th of July, the Bear having arrived on the 27th, the Saturday previous. While we were lying at anchor engaged in the erection of the house of refuge, the rest of the whaling fleet, both sail and steam, gradually arrived and came to anchor off the coast, reaching from Cape Smyth to Point Barrow. After a short stay the steamers went on to the eastward of Point Barrow, following along the ice-pack, which was in sight from Point Barrow, until they reached the heavier ice off Point Tangent. When the last of the whaling vessels had arrived, a fleet of forty-seven vessels carrying the American flag had assembled within sight of the most northerly point of the United States, composed of steamers, barks, brigantines and schooners. These vessels, manned by about twelve hundred men, I venture to say formed the largest assemblage of vessels and men under the American flag to be found anywhere during that year. I cannot speak too highly of the skill, seamanship, courage, and endurance of the whaling masters. They are a fine body of American seamen.

The scene on shore was one of abnormal activity for this region, the erection of the house of refuge, the hasty landing and transportation of stores (in which the whalers assisted), the movements of the Eskimos about their village (which was dotted with the white summer tents of the residents and the visiting inland Eskimos), and the clustering and trading about the Whaling

Company's station (Ray's old station), gave a life and movement which was as shortlived as the season. Fortunately the weather proved most favorable and the heavy ice kept off shore while the stores were landed; the wind then freshened, but communication could still be kept up and the work of erection went on.

The site of the house of refuge is within a few hundred yards of Ray's old house and near the village, and its keeper, Captain Borden (an old New Bedford whaler) was busy in putting his house in order before the autumn should come on. During our stay at this place we were enabled to make a hydrographic survey of the anchorage, which demonstrated that the contour of the bottom is constantly changed by the ploughing and planing done by the heavy ice grounded and driven up by the pressure of the mighty ice-pack, under the influence of northerly winds and gales.

And here let me say a word about the ice of this part of the Arctic ocean. The ice in summer consists of floes and fields of various sizes, which are cemented together in winter by the young or newly frozen ice. No icebergs exist in this part of the Arctic, as there are no glaciers near the sea coast to form them. The shore along the entire Arctic coast of Alaska shows evidence of former glacial action, but the only glaciers to be found are in the southeastern part of the territory.

The Arctic pack, which never melts, consists of hard blue ice, made up of fields and floes of comparatively level ice, which are surrounded and interspersed with hummocks varying from ten to forty feet in height. These hummocks are formed by the broken and telescoped ice resulting from the collision and grinding together of heavy ice-floes, the hummocks being often rounded and smoothed in outline by heavy falls of snow.

In the spring, under the influence of the prevailing southerly winds and northerly currents, the packs break off from the shore and move to the north, the position of the southern edge varying in latitude with the season and the winds.

The shore-ice, which remains fast to the coast line after the pack moves off, gradually breaks up as the season advances, and, becoming scattered, is taken to the northeastward from the vicinity of Point Barrow and northwestward from the vicinity of Herald island and Wrangel land.

Sometimes a long line of heavy floe-ice from the pack grounds in the shallow water near the shore during northerly winds,

pressed from behind by the force and weight of the entire northern pack. It is gradually forced up, ploughing its way through the bottom, at the same time rising gradually along the ascent of the bottom toward the land. The effect of this solid wall of cold and relentless blue ice slowly rising and advancing upon those imprisoned between the ice and the shore is one of the most sublime and terrible things that can be experienced.

The normal current running north through Bering strait forks a short distance to the north, one branch going through Kotzebue Sound and thence along the mainland by Cape Seppings, Point Hope, and Icy cape, to Point Barrow, at which point it goes off to the unknown northeast; the other branch, to the northwestward along the Siberian coast, and thence to the northward toward Herald island. The whalers burned by the Confederate vessel Shenandoah near Bering strait were found in the vicinity of Herald island.

The only portion of the whalers at the time actively cruising had gone to the eastward of Point Barrow. On that day a seaman named Tuckfield returned from the Mackenzie in a whaleboat, and reported the ice conditions unusually favorable as far east as Mackenzie Bay, in the vicinity of which he had wintered. He was a seaman belonging to the whaling station and had been reported to me by a missionary I met at St. Michaels as having visited his station at Rampart house, upon the Porcupine river, a branch of the Yukon.

Upon the 8th of August the house of refuge was virtually finished, and as my orders were to devote my time to the whaling fleet, after the completion of this structure, I concluded to cruise after and with the vessel to the eastward of Point Barrow, leaving the Bear to remain with the vessels lying at anchor off Cape Smyth and Point Barrow. As Tuckfield wanted to go east with his Eskimo guide, I took him and his whale, boat and whaling outfit on board, leaving Cape Smyth on the evening of the 8th. The ice in sight at the time was somewhat scattered, but plentiful, and entering it about nine o'clock we slowly stood on a course parallel to the land. We were occupied in working through this ice all night and all of the next day; it was not the pack ice but shore ice broken off from the vicinity of Point Tangent, Smyth bay, and Harrison bay. At times we found it so closely packed together by current and wind that we had to turn back and work our way closer inshore. Three vessels under sail were sighted

during this time off Tangent point, and by this time we had also demonstrated the uselessness of Little Joe Tuckfield as an ice pilot or prophet. The winds were very light and we had now gotton out of the strong northeast current running off Point Barrow. On the night of the 9th we passed off the north of the Colville river, the water offshore becoming very muddy.

The first important error found in the charts and maps of this region was found here by the observation of the non-existence of the Pelly mountains. This observation was confirmed upon our return by the concurrent testimony of the whaling masters who had cruised here, and the natives who hunt in the neighborhood. The mountains certainly do not exist where placed by the charts, and I judge that some small hummocks near the beach were mistaken for a far off range of mountains, when Dease and Simpson first explored this coast in 1837.

Early on the morning of the 10th of August we sighted the first steam whaler, and as we steamed toward her we skirted along some long low islands parallel to the coast line and stretching from the Return reef of Sir John Franklin to the mouth of the Colville river. The islands, one being about three miles long, are not shown upon the charts, and not having any known names were designated as the Thetis islands.

The steam-whaler was found to be the Balæna, commanded by Captain Everett Smith, one of the most intelligent of the whalemen of the Arctic. He was anchored off Return reef, which he was enabled definitely to locate by the traditions of the natives. It was at this point that Sir John Franklin, in one of his earliest boat journeys, was obliged to turn back while endeavoring to explore the coast from Mackenzie bay to Point Barrow. After a long interview with Captain Smith, from which I gathered much information as to the ice-conditions and the probable positions of the steam-whalers to the eastward, he returned on board of his ship, and the good ship Thetis once more turned her head to the eastward.

Soon afterwards another steam-whaler was sighted, made fast by ice-anchors to an ice-floe; we did not stop, but, exchanging colors, proceeded on our way. The ice seemed to be getting thicker, and shortly afterwards a third whaler was sighted, at anchor off a small low island, with apparently heavy ice ahead. As the weather seemed uncertain I determined to anchor for the night in the vicinity of the island.

The steamer was found to be the whaler Beluga, commanded by Captain Brooks, and the island, though nameless, was marked by a wooden cross, from which fact it was called Cross island. Captain Brooks stated that he had been struggling with the ice to the eastward of Cross island, the day before, in company with some other steam-whalers who had left him and gone to the eastward, so he had turned back and anchored off Cross island. I sounded out the vicinity of the island, finding shoal water to the southward, too shoal for the Thetis to anchor in, and so I remained upon the west side. The wind shifting, our position became insecure on account of the masses of ice drifting toward us; the whaler left the anchorage, stood out into the heavy ice, and made fast to a high hummocky floe. Seeing no good place near by, I held on with the chain on the steam windlass, ready to leave in a moment. Heavy ice coming down and grounding close by on both sides, we left and got out the ice-anchors to a heavy floe, where we rode out the gale until early in the morning, when we were obliged to move on, as the ice packed about our rudder. After moving again and again the wind fell away, the day cleared up, and the ice began to scatter and disappear about the island, the leads to the eastward looking more promising.

The next day at 5 in the morning, in company with our whaling friend, we left the vicinity of Cross island and, entering the ice, stood toward the northeast. The ice-floes grew heavier and larger as we progressed and the canal-like leads more confused, until at 10 o'clock the lead stopped and we both made fast to a very large, long, hummocky floe, at least ten miles in length, several miles in breadth, and aground in 80 feet of water. The day was mild and clear, and, after both of the ice-anchors had been secured and the rope-ladders lowered over the bows, a number of the officers and men went on the ice, the men playing foot-ball and snow balling, while the officers posed for their photographs. This is the time that we were reported (by a steam-whaler that we had passed) as being in a position of extreme danger, and the news was taken to the outside world.

About 4 o'clock in the afternoon we started ahead with the Beluga; the Thetis, now taking the lead, rammed her way through some pack-ice and reached another lead going inshore, the Beluga following very slowly after us. We continued forcing our way until we got into clear water by Lion reef. At midnight we made fast to a small floe and after an anxious night (caused by ice-floes

setting against our stern and rudder) we proceeded, followed at a long distance by the Beluga, which joined us in the afternoon at Camden Bay, and we anchored there for the night. We found that the Beluga in attempting to follow us had gotten on an ice-foot, or protruding spur, and bent her propeller-blades, and had finally to seek another lead out, to the westward of where we had rammed through. As we ran from off Lion reef to Camden bay we sighted the beautiful ranges of mountains close to the coast known as the Franklin and Romanzoff mountains, making an agreeable change in the topography of the shore, which had been low and monotonously flat since leaving Point Hope and the vicinity of Cape Lisburne. We found here that the shore-line was put upon the charts too far north, as our position near Flaxman island, on the west side of Camden bay, was well inland of the coast-line and reefs. Camden bay was the last wintering place of Collinson, in the Enterprise, upon his return from his search for Sir John Franklin, and here we fell in with the track of this distinguished navigator, whose cruise is so little known and whose efforts have been so much eclipsed by his fellow voyager, McClure, who has the distinction given him of being the actual discoverer of the Northwest passage, and who was, indeed, with his little body of men in 1850–1854, the first as well as the last to pass from the Pacific to the Atlantic, north of the American continent.

Upon a long point named Collinson point, and upon the neighboring island known as Barter island, are to be found, during the summer, encampments and rendezvous of Eskimos, who meet there for purposes of trade, similar to the same rendezvous in Kotzebue sound. Here the Alaskan and the Mackenzie river Eskimos meet, also the Lucia or Prat river Indians, who are nomads and come from the vicinity of the Porcupine and Prat rivers, and whose winter rendezvous and habitation is at the Rampart house, a Hudson Bay Company's station and Church of England mission, upon the Porcupine. They are mostly professing Christians and are related to the Athabascans, or Rock mountain Indians, in family. There are no permanent settlements here or elsewhere between the vicinity of Herschel island and Point Barrow. The country is sterile, affording but little upon which to live, the sea also having little or no animal life in its waters. The Eskimos give to this part of the Arctic ocean a native name which signifies *the sea where there is always ice.*

Early the next morning, August 14th, at 5 o'clock, we pushed on in company with the Beluga, standing out of Camden bay and delaying a short time off Barter island, to communicate with the natives. At noon, while off Manning point, the smoke of several steamers was seen to the eastward, and when they had come up we found all but two of the steam-whalers that had gone east. They were led by the steamer William Lewis, commanded by Captain Albert Sherman, probably the boldest and most active of the Arctic whalers. They were all in the cabin of the Thetis in a short time, and I found that they had reached Mackenzie bay and the vicinity of the Mackenzie river. The two missing ones, the Orca and Thrasher, had last been seen in the vicinity of Herschel island. The ice-conditions were reported to be better than those we had passed through. After reflection I considered it my duty, as it was my desire, to go on to the eastward to ascertain the cause of the detention of the two missing whalers, and as time was precious I determined to run on, day and night. By this time night had assumed the conditions of twilight, and the stars had begun to appear in the skies. The threatening appearance of the weather detained us at first, but at 9 o'clock in the evening we got under way, and with her colors hoisted the good ship started again on her easterly course, followed in about half an hour by our old friend and companion, the Beluga. Before leaving we had hoisted out the whale-boat with Joe and native friends, who had been joined at this point by the women of the family. Joe was uncertain about his movements here, and as he expected to secure stores from some of the whalers I left him in their company.

We found the shore bolder as we progressed, and the mountains nearer the coast; as a result, the ice generally sets directly and in heavy masses on the shore without grounding, and this point has never been passed before by the whalers, but fortunately a wide lane was open. The sight of the mountains, standing in their silent and gloomy grandeur, was peculiarly impressive, and our inability to make a closer examination and exploration is to be regretted. So far as I can ascertain, no white man has ever penetrated these mountainous regions, which are known upon the maps in turn under the varying names of the Romanzoff, British, Buckland and Richardson mountains, being so named by Sir John Franklin during his boat journey along the coast. The British mountains are at the extreme northeastern

corner of our territory of Alaska, reaching also across the boundary-line into British America. We passed Demarcation point, where our boundary-line reaches the Arctic ocean, early upon the morning of the 15th of August, and commenced again our cruising in British waters. The character of the shore remained the same, the mountains, however, showing little traces of snow, testifying in this way both to the extreme mildness of the winter and our approach to the valley of the Mackenzie. A few Eskimo huts were seen as we came up to the shoal ground developed by our lead in the vicinity of the mouth of the Malcolm river. The lead was constantly going while we were in these waters, and the ship was steered by it as much as by our compass. In fact the three L's (latitude, lead, lookout) are the great necessities for navigation in these unknown regions, as the three R's are supposed to be in elementary schooling. At 11 o'clock in the morning Herschel island was sighted, this large island forming the western boundary of Mackenzie bay, or, as the ancient explorers often termed it, Mackenzie sea. At 1.30 in the afternoon we anchored off the southwest end of the island inside some grounded ice and off a long gravelly spit, thickly covered with heavy drift-wood from the Mackenzie river.

The island is about 500 feet in height and has a rounded outline, sloping gradually down from the center upon all sides. It shows the appearance of former glacial action, and appears to be an ancient moraine covered with a black vegetable mould. The vegetation was confined to grasses and small Arctic flowers, diminutive in size, delicate in color, and evidently shortlived.

Soon after we anchored a party was sent on shore to erect a sign to mark our visit; it consisted of a board with the name of the ship and the date of the visit in brass letters; under the staff supporting it there are placed in a glass bottle the names of the officers and men of the ship. The Beluga joined us soon after our arrival, and when the party from shore had returned we got under way to continue our look for the two whalers. Captain Brooks came on board the Thetis and shared my perch and lookout in the foretop, while his ship followed, in charge of his mate. As we reached the bluffs at the north end of the island we saw a noble expanse of open water stretching to the northward as far as the eye could reach. The ice was still heavy to the westward and northwestward, but to the north, beyond the light, scattering ice through which we were going, was clear sea, the waves leaping in the beautiful Arctic sunshine.

We looked with eagerness to the sea which stretched, apparently, to the north pole, and then headed to the southward into Mackenzie bay.

After three hours' steaming from our first anchorage we reached the southeast side of the island and found the two missing whalers lying quietly at anchor, Captain Brooks giving a hearty and relieved cry of *Sail ho!*, when the vessels were seen, and we were all pleased to see them safe and secure. We came to anchor close by them and the two captains were soon on board. They reported that they had remained behind to watch for the return of whales from the northeastward, but so far without any success. They had determined to remain until September, and contemplated the possibility of wintering at this place. Soon after we anchored, Eskimos who lived at the mouth of the Mackenzie came on board, and they looked at the ship with the greatest surprise and interest. They had not seen vessels before this summer, though the traditions concerning the "Enterprise" and "Investigator," under Collinson and McClure, still survived.

Sleeping soundly that night, for the first time in many days, the following morning boat parties were dispatched to complete the circumnavigation of the island and to make running surveys in the vicinity.

A small, snug harbor was found and surveyed near-by our anchorage, capable of receiving vessels of less than 16 feet draught; this was named Pauline cove. It would prove a fairly good place for one of the light-draught steamers going up this year to use as winter-quarters.

The waters between Herschel island and the mainland were found after examination too full of shoals and sand- and gravel-bars to form a ship-channel. A rise and fall of tide of three feet was found, and the ship swung regularly to an ebb and flood.

While the boats were out sounding I went ashore and, climbing nearly to the top of the island, had a beautiful view of the clear and open water of Mackenzie bay, to the east and northeast; while to the southeastward were the islands clustering about the shallow mouth of the Mackenzie, and directly to the south were the British and Buckland mountains, merging gradually into the Rocky mountains and the great chains which form the backbone of the American continent.

The temperature of the water and air was found higher upon this side of the island, and I have no doubt but that the climate of the vicinity of Mackenzie bay is materially modified by the comparatively warm water coming out in great volume from the Mackenzie river. The strong current running to the northward from the river would naturally sweep the ice out of the bay and to the northward, as far as the vicinity of Banksland and the extreme northern Arctic.

Where it goes to and where it ceases is now a matter of conjecture. It is to be hoped that the drift-floats which were launched by us from this point, and from various points between here and Herald island, may contribute something to the solution of this question.

As the chances of being shut in by the ice were easily among the possibilities to the whalers who were in our company, and with whose fate our companion the Beluga had joined for the time, the whole question of supplies and retreat was gone over with the whaling masters. A retreat up the valley of the Mackenzie, the Porcupine, and Yukon, seemed feasible, as reindeer were to be found in this vicinity in the winter months.

As the masters of the whalers would not return with me to the eastward, I determined to start back, in order to make my westerly cruise with the sailing fleet. Recalling the boats, we got underway, standing first to the northeast to put over our first drift-float clear of the tidal influence of the waters immediately about Herschel island, and in the open water and northerly current of the Mackenzie. These floats were made of wood about two feet long and nine inches thick, with the name of the ship, the date, and the words, *for drift*, cut upon the face. In a cavity at one end of the float, plugged with soft wood, there was placed a copper cylinder containing a letter requesting the finder to inform the U. S. Hydrographic office at Washington, the nearest U. S. Consul, or the commanding officer of the Thetis, the time and place where the float was found.

After launching the float upon its unknown journey, a lookout was sent to the highest masthead: from there it was reported that to the northward and northeastward there was nothing in sight but open water, neither ice nor ice-blink was visible, and the western entrance to the Northwest passage stretched before us invitingly, as clear and as free as the waters of our own Chesapeake bay. But I had reached my limit, and turning back, to the regret

of many on board, faced once more the icy sea that lay before us toward Point Barrow and the westward.

The weather, however, was superb, clear, cold, and sunny, during the day, while in the now darkening shades of the evening for the first time the moon appeared, silvering most beautifully the chain of mountains along the coast and the fantastic shapes of the grounded ice.

On the 17th we began to meet and overtake the whalers, who still delayed in the vicinity of Camden bay, waiting for whales. Five were passed, some cruising and some fast to the ice-floes. After communicating with them and informing them of our probable movements, we kept on to the westward. The ice-conditions were favorable and we made very good headway, making fast to an ice-floe, off our old island-friends of the midway group, on the evening of the 17th of August.

The wind is always a subject of constant watchfulness and anxiety in this part of the Arctic; it virtually makes the currents and brings down the ice, or sends it off and clears a narrow lane along the shore-line. A northerly shift of wind caused a desire to push on, and passing on we sighted Return reef again and skirted along the long and narrow island which now bears the name of the Thetis. Passing the mouth of the Colville we steamed at a good rate of speed through Harrison bay and found there the wind blowing strong from the west, bringing much ice with it and accompanied by a cold fog. The outlook being discouraging I determined to press on for Point Barrow, not very far distant. The early morning of the 19th of August opened cloudy, overcast, and cold, with a gale and snow from the westward, the ice increasing in quantity and size.

There being no protection from the wind this side of Point Barrow, I ordered full speed so as to get to the point and beyond it before the almost inevitable shift to the northward which would bring the ice down and shut us out. The leads between the ice-floes became narrower and fewer in number, and but little better outlook was found as we edged inshore as far as the shoal water would allow us to go. At this time we sighted as many as eight polar bears on the ice, but this was no time to hunt "bear." Coming to the end of our lead we rammed through some pack-ice into another one, which, however, again led into water too shoal for us. Finding from my perch aloft that the ice seemed even heavier to the west, I determined to stand back to the eastward into the

more open water we had left by the lead we had come through, but it was too late: this lead had closed and we were prisoners in the pack. There being no other place to go, I reluctantly selected the largest pool, or pocket, got out our ice-anchors, and made fast to a heavy floe, to await further developments. It was found to be in slow motion, and four times during the night we had to move to avoid the heavy floes closing in around us. From this time, the 19th, until the morning of the 24th, we were close prisoners in the heavy pack which had set down with the wind, now northerly, between Point Barrow and Point Tangent.

In the words of the Ancient Mariner of Coleridge:

> "The ice was here, the ice was there,
> The ice was all around;
> It cracked and growled, and roared and howled,
> Like noises in a swound."

By incessant watchfulness, almost constant movement, vigorous ramming, faithful working of the engines, and (most important of all) a favorable shift of wind, the good ship, under Divine Providence, escaped without damage or accident. Fortunately within easy reach of land and but twenty-five miles from Point Barrow refuge-station, I had no undue anxiety for life; but I have no hesitation in stating that the readiness, endurance, and subordination of the officers and men of the ship shown in the bringing out of the ship intact from the ice pack, after nearly five days' imprisonment, entitle them to great credit from the proper authorities and justify their commanding officer in the present expression of his high appreciation of their conduct and his warm feelings toward themselves.

About noon of the 25th of August, after a night of hard ramming, we anchored off the west side of Point Barrow, greeted by salutes from the whalers anchored there and by the hearty congratulations of the masters, who soon came on board and learned for the first time that Mackenzie Bay had been reached.

We found that the sailing fleet had gone to the westward, after having been shut in by the ice coming down on Point Barrow and Cape Smyth for several days, during our absence. The few whalers that remained had been watching us from their crows' nests during our imprisonment, but were unable, of course, to afford us any assistance, each ship having to work out her own salvation: companion-vessels are of great service only in case

of damage or abandonment. Fortunately, the steam-whalers remaining behind us did not have the pack set down upon them in the shallow bights in which they were cruising, and the long continued north-easter which aided us in our escape enabled them to find leads to get through, not very long after we had escaped. We remained at Point Barrow for a week until they had all returned, except the two most easterly ones, left at Herschel island. As their return was so uncertain, at the end of a week I dropped down to the house of refuge at Cape Smyth, landing provisions to fill the deficiency in their stores, and went to the westward, first going to Icy cape to erect a needed beacon as a warning of the vicinity of Blossom shoals.

Leaving this vicinity on the 5th of September for the northward and westward, and rounding Blossom shoals, we stood to the north, reaching the supposed vicinity of the edge of the ice pack that night. As the nights were now dark we lay-to until morning, when the rapid fall of the temperature of the water and the lessening wind gave indications of its proximity, and a half hour's steaming brought us to the rugged white outline of the pack. Along this we skirted, having reached our highest north (less than 72° N. latitude).

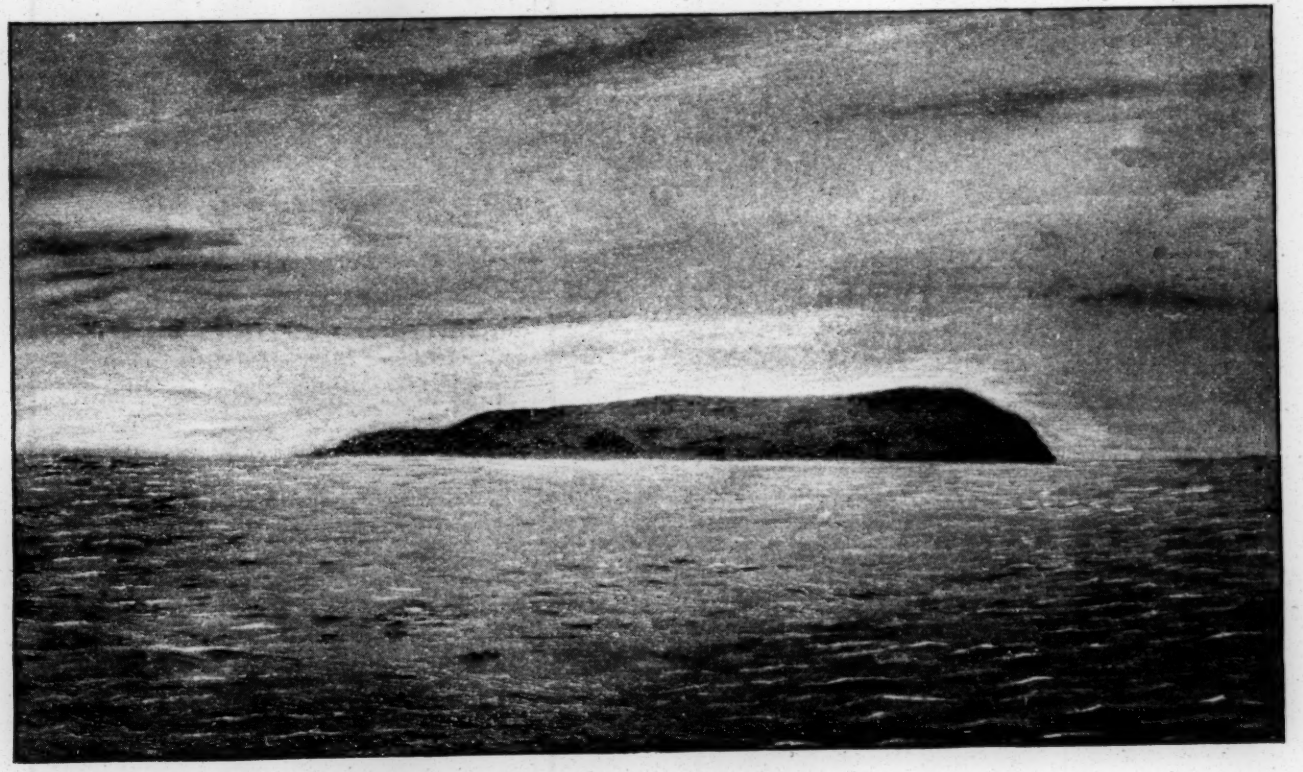
All of that day and the next we continued our course, sighting a portion of the sailing fleet of whalers on the 7th. Communicating with them of our proposed movements and whereabouts during the rest of September and the beginning of October, we then stood to the westward. I must not forget to mention an interesting incident that occurred. A schooner stood down to us from the fleet, and was recognized as the schooner Jane Grey, picked up by the Thetis when under the command of my predecessor the previous summer in the ice—abandoned. She had been righted, pumped out, repaired, and restored to her owner, who had literally sold his farm and put his all into the vessel. As he came within hail our notification was given him, but I noticed that he fairly danced with impatience during its delivery, which was accounted for at the end of the message by his bringing out his men, who were gathered behind the foresail, and giving hearty and prolonged cheers for the Thetis which fairly rang in the silent Arctic air. To this we responded and then went on our way.

We now left the pack and steered through open water for Herald island, which we sighted at half past twelve the next day,

the 8th of September ; as we approached it closely the bareness and forbidding appearance, which had been concealed at first sight by the bluish dimness of the outline, became very marked. Its sides were almost inaccessible, except from the western end, and it was free from ice, an almost exceptional state of affairs. In close seasons it is impossible to reach it, and, even more than Point Barrow, it may be shut out of the world by ice that refuses to move during the short summer.

We passed the island late in the afternoon within a comparatively short distance, standing on to the west with the hope of seeing Wrangel land before dark. At half past five land was reported ahead from aloft, and soon the high snowy peaks and mountainous outline of Wrangel land was sighted from deck. It stood out beautifully in the late Arctic afternoon, and as we approached it more closely its outline became more and more fantastic and brilliant. At sunset we were a little over ten miles distant, and at dark, as we turned to the southeast for Point Hope, we exchanged hearty congratulations upon our successful passage from Mackenzie Bay to Wrangel land. Arriving at Point Hope upon the evening of the 10th of September, we found that many of the hunting parties had returned from the interior, and preparations were going on for the winter season.

The natives of Point Hope, like the Eskimos generally of northwestern Alaska, have no tribal or other form of government except what exists by control of the head man, oomalik, or chief, whose superiority arises from his wealth and influence. The previous chief had lived a life that made him a terror to the community. His rule was by force alone and by the influence of the rifle, which was his inseparable companion. After a career distinguished for license, murder and robbery, he had come to a timely end by being assassinated by the brother of a wife he was tormenting to death. Since his death, up to the time of our stay in September, anarchy had prevailed. On account of the very indifferent treatment received by the survivors of the wrecked whaler "Little Ohio" from the Eskimos at Point Hope the previous winter, I determined to appoint a head man or chief who would be charged with the responsibility and duty of caring for any shipwrecked persons or destitute whites. Anokolut, who was appointed by me and whose appointment was afterwards confirmed by the Governor of Alaska, had married the niece of the previous chief, and was the best whaleman and hunter of



Herald Island, bearing about W. by S. (magnetic).

From a photograph by Assistant Paymaster J. Q. Lovell, U. S. N.

the district. He had been in the employ of the whaling station established the previous year at Point Hope, and had been satisfactory in all his dealings with the whites. His wife was a very superior woman, and their desire for civilized usages was so great that a bread-pan of tin, some granite-ware bowls, and candles, were given and eagerly accepted as contributing to make their domestic lives more comfortable and civilized. An urgent request was made for a cooking-stove, which I promised to give them if I should return the following summer.

The Eskimo lamp which serves as a light, and to some extent as a stove, is a crescent-shaped stone utensil with a shallow trough scooped out; this is a receptacle for the whale-oil, the wick being some native moss laid along the edge of the lamp and trimmed from time to time, the supply of oil being kept up by a lump of blubber suspended over the lamp. The light being indifferent, candles are welcomed as a great improvement and a marked relief to the over-taxed eyes of the men and women during the long nights of the Arctic winter.

During our stay at Point Hope we found much of interest in connection with the Eskimos living there. Their long winters give them an opportunity to keep alive their traditions in their daily meetings in the council-house, and they give an account of their early days in this wise: In the beginning the people had heads like ravens, with eyes in the upper part of their breasts. All the world at this time was wrapt in gloom, with no change of day and night. At that time there lived a powerful chieftain on top of the highest peak. In his hut were suspended two balls that were considered very precious and were therefore carefully guarded. One day, the chief being absent and the guards asleep, some children who had long admired the beautiful balls knocked them down with a stick and they rolled across the floor of the hut and down the side of the mountain. The noise awakened the guards, who hurried after them, while their extraordinary beauty attracted the attention of the people, who also rushed after them, a wild struggle ensuing for their possession; this ended in the breaking of the balls. Light sprang from one and darkness from the other; these spirits of light and darkness claimed sole dominion, but, neither yielding, a compromise was made by which they agreed to an alternate rule. The violent struggle for the mastery so disturbed the world that the anatomy of the people and the surface of the

earth were both changed. Light being upon the earth, men began to catch whales in the sea and to carry the flesh and bones to their mountain-homes. One family wandering over the country recently risen from the sea came down upon Point Hope: finding vegetation springing up and whales abundant, they built a hut and made it their home. From this originated the settlement at Point Hope. Their modern history goes on in this wise: Point Hope being favorably situated for whaling and hunting the seal and walrus and for obtaining the reindeer, it naturally became a center of power and population. In the latter part of the eighteenth century, as well as can be determined, the village upon Point Hope, known by the natives as Tigara, had a population of 2,000 souls, with six council-houses. At that time the Eskimos residing upon the Noatok, or Inland river, began to encroach upon the territory of the Tigaramutes until matters came to the pass that about the beginning of this century a great land- and boat-fight took place between the Tigaramutes and the Noatokmutes near Cape Seppings, in which the Tigaramutes were defeated and forced to yield a large portion of the territory formerly controlled by them. So crushed were the Tigaramutes that they lost one-half of their population, which led to the gradual abandonment of all the outstanding villages. Since this time the population has gradually decreased, the diminution being materially aided by the contact of whites, who are principally represented here by the crews of the whaling ships, rendezvousing during the early summer.

As a rule the Arctic coast Eskimos are short in stature, the average height of ten men measured at Point Hope being 5 feet 5.8 inches, and of ten women, 5 feet 2.4 inches. The legs are short in comparison to the length of the body and are always much bowed, this being due to the manner in which they are carried in infancy upon their mother's back, the legs being brought tightly around under the mother's arms. The feet and hands of the women are generally well shapen and small.

All of the Eskimos have good teeth, but as they are subjected to severe usage they deteriorate in every way. They are used as substitutes for pincers, carpenter's vices, and fluting machines. They are used in drawing bolts, untying knots, holding the mouth-piece of a drill, shaping boot-soles, and stretching skins. When they become uneven from constant use in this way, the unevenness is corrected by a levelling down by means of a file

or a whetstone, until they finally reach a level too low for mechanical purposes.

Between sixteen and twenty-two years of age the male natives have their lips pierced under each corner of the mouth for labrets.* The incision is made and at first sharp-pointed pieces of ivory are put in; when the wound heals the hole is gradually stretched by inserting larger labrets until half an inch in diameter is reached. The poorer natives wear labrets made of coal, walrus ivory, common gravel, and glass stoppers which they obtain from ships and adapt to this use. The stopper of a Worcestershire sauce bottle is very useful for the purpose. The richer ones have agate labrets, the most valued one, however, consisting of a white porcelain-like disk 1½ inches wide, in the center of which is mounted a turquoise nut, hemispherical in shape, nearly an inch wide, fastened with a spruce gum obtained from the interior. We could not ascertain where the turquoise or porcelain-like disk was obtained. The Eskimos say they have always been in the country, and sell them only with the greatest reluctance.

Tattooing is general among the women, and is apparently a custom of great antiquity. At the age of six one narrow line is drawn down the center of the chin from the lower lip downward, powdered charcoal being used as coloring matter. At twelve years the line is broadened to half an inch, and a narrow line made parallel to it on each side. But I will not detain you by giving other particulars.

On the 20th of September the Thetis left Point Hope for the south, the rugged season of the Arctic ocean having fully set in. Strong winds and gales from the northeast had compelled us to move from the northern to the southern side of Point Hope, where better protection and anchorage had been found. On the 21st of September we passed out of the Arctic ocean and through Bering Strait, reaching Ounalaska again on the 26th of September. After remaining there until the beginning of October the ship returned to Sitka, and after a prolonged stay in the waters of southeastern Alaska we finally reached the Golden gate of San Francisco, shortly after midnight on the 7th of December.

* *Labrets* is the name used along the coast for the lip-ornaments worn by the natives.

The cruise of the Thetis was remarkable in several respects, among others in that, thanks to the open season, her stanch build, and successful battling with the ice-pack, she was enabled to reach Mackenzie bay, in British North America, the first government vessel to carry the American flag in those waters. She also made the long stretch from Mackenzie bay to Herald island and Wrangel land in one season, never before done, and she had the honor of being the first vessel of any kind to follow the entire main coast line of Alaska from Port Tongass, in extreme southeastern Alaska, to Demarcation point, in the Arctic ocean.

THE LAW OF STORMS,

CONSIDERED WITH SPECIAL REFERENCE TO THE NORTH ATLANTIC.

By Everett Hayden.

(Abstract of a paper read before the National Geographic Society, Nov. 15, 1889.)

In preparing an abstract of this paper it is of course difficult to adhere very closely to the original, inasmuch as that was illustrated by forty-five lantern slides, while it is only practicable to present a few plates with this abstract. I may therefore be permitted to give only a general outline of the subject, with perhaps a more detailed discussion of one or two of the most notable recent hurricanes off our Atlantic coast.

The term "Law of Storms" is applied to the code of rules that should govern the action of the master of a vessel when he has reason to suspect the approach of a dangerous storm. It will be seen that this definition, like the code itself, is somewhat vague. So many considerations enter as factors in the question that it is wholly impossible to lay down any rules that shall be applicable alike to a high-powered, well-manned steamship, and to a heavily-laden, poorly-equipped and short-handed sailing vessel. Disregarding such differences of conditions (which are, of course, of vital importance in each individual case, but which cannot be discussed in a brief general essay), the two grand divisions of the subject may be compared to *grand strategy* and *field tactics*. By this I mean that a broad, comprehensive view of the whole subject of ocean storms—their regions, seasons, size, severity, and tracks—is one very important part of the navigator's duty in planning a long campaign, or voyage; and, secondly, the handling of his vessel when actually in the fight—the coolness, clear-headedness, and trained experience that utilizes every resource of the best seamanship and navigation in a fearful struggle with the fury of a hurricane—all of these are also an essential part of the education of the ideal sea-captain.

Thanks to the progress of meteorologic research it is comparatively easy nowadays for anyone to get a very good general idea

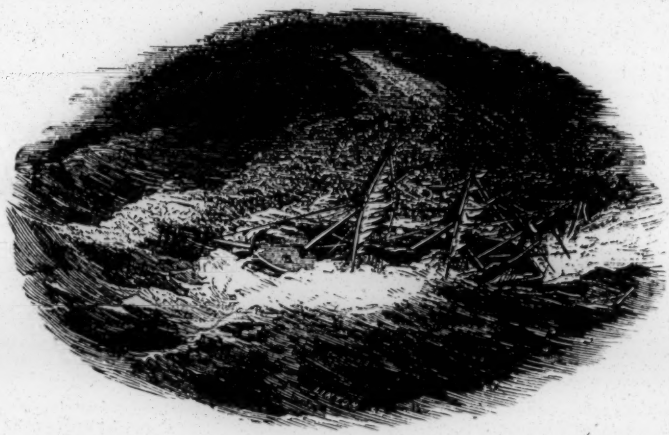
of the great hurricane regions of the globe, and the seasons when these dreaded tropic cyclones prevail in each of these regions. The evidence on this subject is cumulative and practically conclusive, so that it is universally known and recognized that the hurricane months are the summer months in each hemisphere ; hurricanes originate in the tropics, move westward, then poleward into the temperate zones, and finally eastward in higher latitudes, receding gradually from the equator ; moreover, the essential difference between hurricanes north and south of the line is as follows : In the Northern Hemisphere the rotation of the cyclonic whirl is *against* the hands of a watch, and in the Southern, *with*. The noted hurricane regions are the West Indies, coast of China and Japan, Bay of Bengal (especially in May and October, at the time of the change of the monsoons), and the South Indian Ocean (about Mauritius). Less noted regions are the South Pacific (East of Australia), the North Pacific (west of the Mexican coast), and the Arabian Sea. In planning a distant voyage a navigator should therefore consider the hurricane regions through which he must pass, just as he considers the prevailing winds—the trades, monsoons, and ocean currents.

The handling of a ship in a hurricane is a very different sort of a thing from this general survey of the entire field, and, without the eminently practical qualities that we all associate with a good officer of the navy or mercantile marine, no mere theoretic knowledge can avail much. And yet this is one of those cases where practice and theory should go hand in hand,—not theory as something vague and unreal, but theory as based upon a firm foundation of observed facts. If a vessel encounter a hurricane, certain conclusions can be drawn from observations of the shifts of wind, the fluctuations of the barometer, the appearance of the clouds, and the direction of the ocean swell ; the master of that vessel will undoubtedly draw such conclusions, and store them away in his mind as part of his fund of experience upon which to base action at some future time. But if he can consider his own observations, while fresh in mind, in connection with the observations made on board many other vessels that encountered the same storm, and modify or verify his conclusions by such comparison, there cannot be a doubt but that the lesson will be of far greater value. Sailors lead a rough life, and their training is often acquired by experience alone. Moreover, there are certain things that tend to discourage effort on the part of junior

officers, even on board naval vessels : they realize that their duty is not to originate orders but to execute them, and sooner or later they get out of the habit of reflecting upon the action taken to avoid a storm or manoeuver in one, not knowing at the time what considerations lead to the action that was taken, and not always having anything brought forcibly to their attention to indicate with certainty whether the action was well-considered or ill-advised. Upon finally attaining command themselves they are not, therefore, as well posted as they might otherwise have been. I mention these things to explain the undoubted fact that comparatively few masters of vessels are well posted in certain very important additions to the old law of storms, as it was discovered by Redfield and enforced by Reid, Piddington, Thom, and other early writers. In fact, of all the navigators of various nationalities who have charge to-day of the commerce of the world, probably four-fifths are wholly ignorant of the progress that has been made in this direction in the past fifty years. That such is the case is not, in my opinion, wholly their fault : it is owing to the fact that far too little attention has been paid to clear, forcible, and convincing explanation; it is the fault of the teachers, no less than the scholars,—of meteorologists who talk over the heads of their audiences, instead of stating facts and conclusions in a way to command attention and respect from the practical men who furnish the data, and who deserve some tangible results in return for their long years of voluntary observation.

It is difficult to put this matter very clearly to those who are not familiar with the conditions that govern the management of a vessel at sea, and I shall only attempt to do so in a very general way. It should be understood, first of all, that a hurricane is an enormous whirlwind, so large, in fact, that its circular nature was generally recognized only about fifty years ago. At the immediate center of the whirl there is a calm space, from five or ten to thirty or forty miles in diameter, generally with blue sky and bright sunlight. Within a short distance of this central calm the wind blows with frightful violence, and here a vessel is driven along in absolute helplessness, enveloped in midnight darkness, buried in a flying mass of foam and spray, with every sound annihilated by the roar and shrieks of the elements. The core of the hurricane, as this region has been called, is small, relative to the entire area, and it thus happens that a few miles may make all the difference between shipwreck and safety. The ques-

tion is, then, to avoid getting into the core, or heart, of the hurricane. It is evident enough that if the wind blow in a strictly



A ship in the heart of a cyclone. From Reid's "Law of Storms."

circular direction around the center, the bearing or direction of the center must be at exactly right angles (eight points) to the right (or left) of the direction of the wind. In other words, in the Northern Hemisphere (where the direction of rotation is against the hands of a watch) the center bears eight points to the right of the wind (that is, to the right of the direction from which the wind blows); in the case of a hurricane off our coast, for instance, if the wind be NE. at Hatteras the center would bear (according to the 8-point rule) SE. Considering, further, that the entire whirl has a progressive motion along a path, or track, if an observer at Hatteras find that the NE. wind freshens rapidly, without any shift or change of direction, it is equally evident that the center of the storm is approaching directly toward that point. In a similar situation at sea, a shipmaster would naturally see that his vessel was in a position of great danger: evidently the best thing to do would be to run before the wind, thus getting out of the way of the approaching hurricane. This simple case will explain pretty clearly, I think, how rules were at once formulated and adopted, as soon as Redfield had proved the approximately circular character of these storms.

Without going further into this subject, inasmuch as this 8-point rule is perhaps the most important of all the rules—indeed, all of them follow directly from it,—suppose that subsequent re-

search, based upon careful observation and the accurate charting of hundreds of reports from vessels in similar storms in various oceans, proved conclusively that the wind in a hurricane does not blow in strictly circular whirls, but rather spirally inward, so that with a NE. wind off Hatteras the center bears probably S SE., or even South: evidently this is a matter of vital importance to the navigator, and all the old rules should be remodeled to suit the discovery. Such is, indeed, actually the fact, and in most cases nothing could be worse than to run directly before the wind; in any event it would be dangerous, and in the case of a slow-moving cyclone it might readily lead the vessel directly into the core of the hurricane. This is known to have been the case in many instances, and vessels have thus been drawn into the inner whirls of hurricanes and kept there for several days, making one or more complete revolutions around the center before they could extricate themselves. In fact, they might never have gotten out, if the storm itself had not moved off and left them.

The first of the accompanying plates, entitled,

WEST INDIAN HURRICANES, AND OTHER NORTH ATLANTIC STORMS,

gives a brief and yet complete résumé of what is perhaps the best modern practice. In these brief statements the attempt has been made to put concisely, intelligibly, and *completely* (if one will but read each and every sentence as carefully as they were written), the very latest, most important, and best-established facts, with which every navigator should be familiar. The paragraph entitled "Intensified trade-wind belt," for instance, is very important. A close consideration of the caution expressed in these few lines may prevent a serious mistake that might be made by a too rigid adherence to the old rules. The idea is as follows: It has been proved by Meldrum, from his studies of Mauritius hurricanes, that the SE. trade-winds blow toward a part of the *track* of a hurricane, rather than at right angles to the direction of its center, and it is therefore unsafe to assume that the center bears at right angles to the wind, or that, because the trade wind increases in strength without any decided change of direction, the center is approaching directly toward the vessel. This principle might naturally be expected to hold for similar storms in other regions, and Abercromby, in a thorough study of

the whole subject, has shown that such is the case, although he states that "the position of this belt [of intensified trades] differs in every hurricane region, so that a special set of rules are necessary for each country." It seems to me, I must say, that in the absence of such special rules the law may safely be assumed to be general; its importance to navigators is certainly very great, and its principal effect must be to urge the greatest caution in making any attempt to cross the track of a hurricane, from the dangerous to the navigable semicircle.

The next plate,

THE HURRICANE OF NOVEMBER 25, 1888,

is a very instructive illustration of an actual hurricane, and one of the most severe on record off our Atlantic coast. The spiral lines have been added to bring out conspicuously the wind-circulation, and several features will at once attract attention: the elongated shape of the storm, along a north and south line (the direction of motion); the wide region where there is a southeasterly gale (exactly analogous to the belt of intensified trades); the long sweep of northeasterly winds along the coast; and the marked variation from a strictly circular whirl. The right-hand side is the dangerous semicircle, and it is here that the navigator is called upon to decide whether he shall dare make the attempt to run before the wind and cross the track of the storm; the left-hand side is the navigable semicircle,—not very *navigable* in this particular case, we may well believe, with no sea-room to the westward, a fearful N NE. gale, and a terrific sea. This is a case where every resource of seamanship and navigation may fail to save a ship, as the loss of the steamship "Samana" and a dozen other strong vessels, with all on board, bears sad testimony. Let me quote a few lines from a thrilling report by Captain Drew, of the American ship "Sea Witch" (this vessel's position is plotted on the chart about lat. 32°N., long. 75°W.): "Nov. 24: Hurricane from NE.; our position a perilous one, the ship rolling heavily and filling the decks with water; an awful gale, the worst we have ever had,—how will it end? At 3 P. M., the sun out a moment through the thick sky. Nov. 25: Still blowing a hurricane, with awful squalls of rain; the seventh day of the gale. No side-lights can burn; the binnacle-light goes out as fast as we can light it. One blast from the north blew our brand-new lower-maintopsail away like brown paper. We performed

the critical manœuver of wearing ship, which saved the vessel: we were foundering." Verily, this was "out of the jaws of death," and probably there were few more sincere thanksgiving services than those held on board this vessel on Nov. 29th, 1888, as recorded in her log. One other report may be referred to here, as it is of especial interest. It is from the British steamship "Effective," whose position is plotted about half way between Bermuda and New York. At this time the wind was S SE., force 8, and the storm center was moving directly toward her. We learn from Captain Crosby's report that by noon, local time, the wind was strong from south; at 4:30 P. M., a hard gale from east, moderating until midnight, barometer falling very rapidly. Nov. 26th, very heavy gale from NE., ship heading bow to sea; noon, wind east, barometer 28.60; 5 P. M., wind N NE., 28.20; 10 P. M., SW.; midnight, W., 28.20. This report illustrates the experience of a vessel close to the line of sudden shift of wind from SE. to N NE., and sustains very well the spiral lines drawn on the chart, just where there is an absence of data on the chart itself.

Lack of space does not allow of further details, and I must go on to the next plate,

THE ST. THOMAS–HATTERAS HURRICANE OF SEPT. 3–12, 1889.

This plate is copied exactly from a Supplement issued with the Pilot Chart for October, 1889 (published Sept. 27th), with only the addition of the tracks of the two storms (as indicated by later data) and the tracks of a few vessels (see small charts dated Sept. 3, 4-7, 10). Considering the early date of publication, the wide expanse of ocean covered by the charts, and their essential accuracy (as indicated by later data), it must be acknowledged, I think, by anyone who is at all acquainted with the difficulties incident to this sort of work, that this supplement to the Pilot Chart hit more closely to the truth in this matter than would probably be possible under similar circumstances in one case out of ten. Had later data materially modified conclusions drawn at such an early date, it could not have been a matter of surprise, although this prompt publication would still have served a most valuable purpose in interesting navigators to contribute data likely to help us in establishing the facts. Indeed, the following quotations from the Pilot Chart and Supplement illustrate exactly what was desired, and what was actually accomplished

by this publication: "This preliminary publication, issued two weeks after the storm reached our coast, well illustrates the cordial support this office receives from masters of vessels in its efforts to collect and utilize data regarding marine meteorology. It is desired to collect as complete data as possible regarding this storm, in order to publish a final report, and the present publication will be useful as a good working basis for a more complete detailed study of the hurricane." Also, "Special attention is called to the fact that this preliminary publication is only intended to give a brief outline of the facts as indicated by data received up to date of publication." Moreover, the name, nationality, and rig of every vessel whose report had been received in time to be used was published, and every statement made in the accompanying text was based on an exhaustive study of all the data.

It is interesting to note how slightly the very complete data now at hand have modified this hastily-prepared history, and all the circumstances urge similar quick work and prompt publication in every case, before other storms and other conditions have dulled public interest and directed attention elsewhere. The track of the easternmost of the two storms, as plotted on the first little chart, shows that it moved more rapidly than was anticipated, and recurved farther north: the fact is, its very existence was not even suspected till *two hours* before the final draft of the maps was made, and then only because the German steamship "Savona," from Baltimore for Brazil, suffered such damage from the hurricane on Sept. 5th (see chart dated Sept. 3rd for position) that she was obliged to run in to St. Thomas for repairs, and our consul, Mr. M. A. Turner, forwarded her report by the first steamer to New York. The following is a brief extract from this report, beginning at 10 P. M., Sept. 4th: "Full hurricane, ship lying in trough of sea, laboring heavily and shipping much water. Cargo shifted; jettisoned 600 barrels of flour and 60 tons of coal. Broke steam steering gear and wheel, found rudder adrift, 3 feet of water in the hold, foundations of engines seriously loose and getting worse. Bore up for St. Thomas."

It is impossible, in the space at my disposal, to refer even briefly to the reports of the few vessels whose tracks are plotted on the charts: the stanch steamship "Earnmoor," foundering in the heart of the hurricane on Sept. 5th, eleven of her crew of thirty escaping in an open boat, and of these only seven surviv-

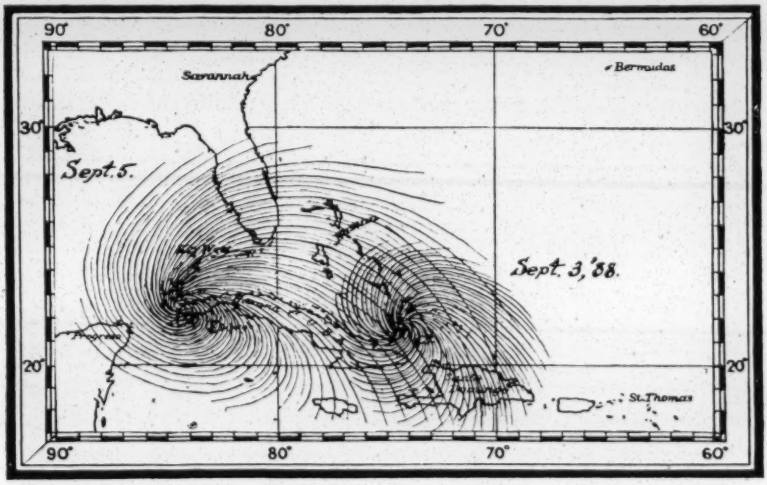
ing that fearful drift of twenty-three days; the "Sépet," between the two storms and escaping both; the "Lassell," from the tropics to Block Island, all the way in the grasp of the hurricane, without a sight of sun, moon, or stars, to fix her position; the "Ada Bailey," rolling in the long swell off Hatteras and watching the early indications of the approaching storm for nearly a week before it struck her; the "Hernan Cortes," forced to stand off into fearful danger by the still greater danger of a lee-shore at Hatteras; and the "City of New York," "Teutonic," and "City of Rome," starting on their Titanic race from Liverpool for New York the day after this great hurricane swept past St. Thomas, and reaching their goal with it, and in spite of all its fury. I must dismiss this whole interesting history with the following abstract of the report of Capt. Simmons, of the British brigantine "Victoria," whose original report is brief and to the point, like all the rest (see track of the "Victoria," northwest from St. Thomas, on the first small chart):

> I passed through the cyclone, resulting in the total loss of the spars, sails, etc., of my vessel. The SE. sea became so heavy that I was obliged to heave-to. The sky was one sheet of dark gray, at times approaching black. The lightning was excessive only during the latter part of the storm; it appeared as a continuous quivering sheet around a great part of the horizon, extending about 10° above it and lasting many seconds, unaccompanied by thunder; the compass could not be read, the card spinning so that the points were indistinguishable. The lowest barometer reading was 27.86 (aneroid, corrected by comparison at Boston shortly before and at Halifax the following month).

The importance to navigators of a true appreciation of the law of storms—not the mere memorization of a set of rules, but an intelligent comprehension of the subject—is now perhaps clearly evident to the reader: at any rate, that is the object I have aimed at, rather than a mere formal statement of generally accepted principles and an abstruse discussion of isobars and gradients.

It will be seen that *the probable bearing of the center, as indicated by the direction of the wind at a single station*, is the great question, so far as the navigator is concerned. There are men who want and must have a hard-and-fast rule,—an 8-point, a 10-point, or a 12-point rule—something to act on without thought, while every nerve is strained to save the ship's spars, sails, boats, engines, and cargo, from damage or destruction. Under such circumstances, I think that perhaps the safest general plan is to use the old 8-point rule, but *applied to the low clouds, instead of to the wind.* This is equivalent, generally speaking, to a 10-point

rule, applied to the wind. That any such rule, if intended for general application, is only roughly approximate, goes without saying, or ought to do so, at least. The angle of bearing changes in different parts of the storm, it varies with the quadrant, with the latitude, with different storms, and with various other conditions, too numerous to be mentioned or even wholly known. One good general rule is that in rear of a hurricane the wind blows somewhat decidedly toward it; and yet that there are marked exceptions is well illustrated by the chart of the hurricane of November 25, 1888, already referred to. As a good example of the wind circulation in a hurricane in the tropics the accompanying diagram is of interest. This represents two days



The Cuban Hurricane of September, 1888, illustrating the surface wind-circulation on September 3d and 5th, at noon, Greenwich mean time.

(the 3d and 5th) of the great Cuban hurricane of September, 1888, the intervening day (September 4th) being omitted, for the sake of clearness. Its severity is sufficiently indicated by the fact that it caused the loss of fully a thousand lives in Cuba, and destroyed property of the estimated value of $5,000,000 in the single province of Sagua. Now take any point on any one of these spiral lines, and observe the bearing of the center: in rear of the storm, especially, the 8-point rule is hardly applicable, and action based upon it might result disastrously.

The next and last plate, entitled,

HURRICANES IN THE NORTH ATLANTIC.—TYPICAL CIRCULATION OF THE WIND, FROM ACTUAL OBSERVATION,

gives a still more complete illustration of the wind-circulation in hurricanes, with a brief discussion of the application of the 8-point rule. Especial attention is called to the statement made thereon (referring, of course, to hurricanes in the North Atlantic, but no doubt true for the entire Northern Hemisphere) that

"although the 8-point rule is nearly true when the wind is anywhere from north to south by way of west (that is, generally speaking, in the navigable semicircle), it is liable to be a very poor guide when the wind is from any point in the first or second quadrant."

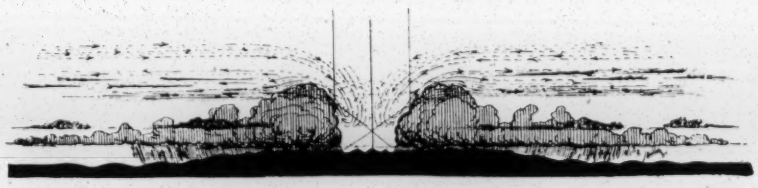
Also to the following, which is applicable to the Southern Hemisphere by the substitution of "to the left" for "to the right :"

"Perhaps the best general rule is that the center bears about eight points to the right of the direction from which the low clouds come, or, what is practically the same thing, eight points to the right of the wind at the moment of a sudden shift in a heavy squall : after such a shift the wind will remain steady in direction for a time, but the center is meanwhile moving along and the angle of bearing changes until the next shift, when it goes again to eight points, and so on."

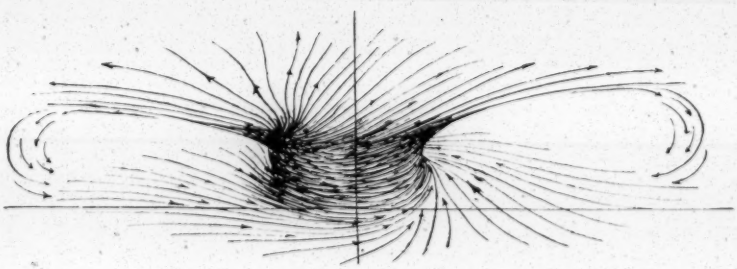
Such diagrams, carefully prepared from complete and reliable data, are of far greater practical value to navigators than volumes of explanation : they appeal to the eye and will live in memory long after ideas conveyed by printed words have been forgotten.

Finally, let us look for a moment at two sketches that I have made to give a graphic and I hope not incorrect idea of the cloud formation and the internal structure of a hurricane. In both sketches the vertical scale is of course greatly exaggerated. The first illustrates particularly the great cloud bank (with the "bull's eye," or clear central space, shown in cross-section); the storm-wave or general elevation of the surface of the ocean caused by the spirally in-blowing winds and low barometric pressure (the cause, oftentimes, of fearful floods along low-lying coasts); and the probable, or possible, circulation of theupper atmosphere over the whirl, together with the direct and reflected rays of a vertical sun as they pour into the central calm. The second sketch is to aid a clear mental conception of

the actual motions of the particles of air as they flow inward below, whirl about the central core and flow outward above; this may help to free the mind from an erroneous idea that may be suggested by thinking of or seeing the enormous, piled-up, apparently stationary mass that constitutes the *barra*, or cloud-bank of the hurricane, but which is really only the stationary and visible *locus* where the conditions are such that the whirling, rushing masses of humid atmosphere condense their tons of aqueous vapor and leave it, as they pass upward and outward.



Sketch, in cross-section, to illustrate the cloud-formation, storm-wave, etc., in a hurricane. The dotted lines represent the probable circulation of the upper atmosphere.



Sketch, in perspective, to illustrate graphically the lower-atmosphere-wind-circulation in a hurricane. The inward spiral at the base is the surface wind.

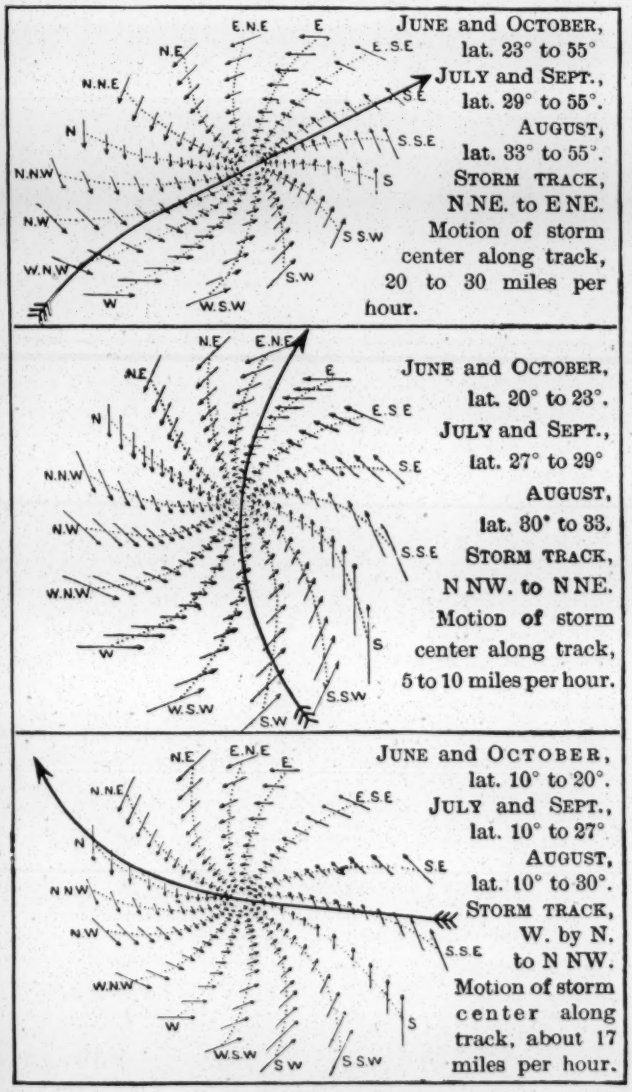
It is analogous to the cloud-cap, or banner, that hangs stationary over a lofty mountain peak, although if you visit the peak you may there find a living gale of wind.

In both of these sketches my object has been to try to convey an idea of the marked individuality, symmetry, and intensity of a tropic cyclone, and its grasp upon and intimate connection with the ocean, which it joins to the upper atmosphere by a huge, hollow trunk, with widely extended roots and spreading branches, —no doubt an enormous and effective conductor of atmospheric electricity, too, whose power is quickly shattered and destroyed by contact with the land; the notable absence of thunder (illus-

WEST INDIAN HURRICANES, AND OTHER NORTH ATLANTIC STORMS.

From the Pilot Chart of the North Atlantic Ocean, August, 1889, with Additional Paragraphs.

Explanation.—These diagrams are for practical use in West Indian hurricanes. The upper one will also answer for ordinary storms along the transatlantic route. The small arrows fly with the wind, the direction being stated at the end of each dotted line; the long arrow on each diagram is the STORM TRACK, that is, the probable path of the cyclone through the belt of latitude to which the diagram applies.


JUNE and OCTOBER, lat. 23° to 55°
JULY and SEPT., lat. 29° to 55°.
AUGUST, lat. 33° to 55°.
STORM TRACK, N NE. to E NE.
Motion of storm center along track, 20 to 30 miles per hour.
JUNE and OCTOBER, lat. 20° to 23°.
JULY and SEPT., lat. 27° to 29°
AUGUST, lat. 30° to 33.
STORM TRACK, N NW. to N NE.
Motion of storm center along track, 5 to 10 miles per hour.
JUNE and OCTOBER, lat. 10° to 20°.
JULY and SEPT., lat. 10° to 27°.
AUGUST, lat. 10° to 30°.
STORM TRACK, W. by N. to N NW.
Motion of storm center along track, about 17 miles per hour.

[*Edition of July, 1890.*]

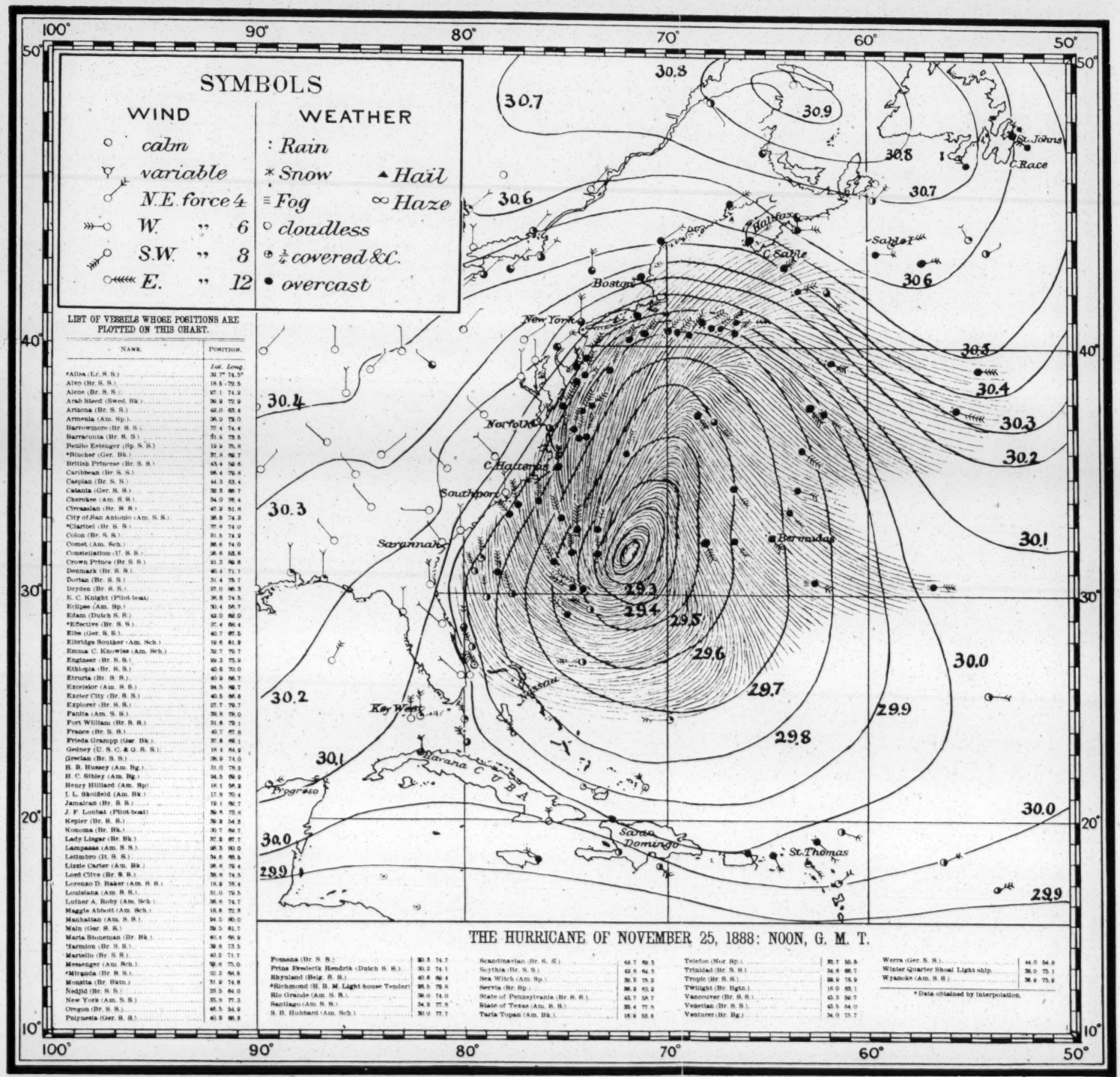
Use of the Diagrams.—When a falling barometer, freshening rain squalls, &c., indicate a hurricane, select the proper diagram (according to the MONTH and LATITUDE), plot your position upon it by means of the direction of the wind, and thus ascertain the approximate bearing of the storm center. The probable storm track is indicated by the long arrow. If the wind shift, plot your position by means of the new wind-direction (nearer the center if the wind has freshened and the barometer has fallen). In this way you can readily observe every change of position relative to the storm center, and decide what action to take, according to the character of your vessel, the lay of the land, &c. These storms vary greatly in size, but are smallest and most violent in the tropics, where the cloud ring averages about 500 miles in diameter and the region of stormy winds 300 miles, or even less. You can therefore only roughly estimate the DISTANCE of the center, although its BEARING can be obtained from the diagrams with a high degree of probability. There is also considerable variation in the direction of motion and the velocity of the storm along its track, but the general tendency is as stated herewith.

Cyclonic Circulation.—One of the most important indications that an approaching storm is of hurricane violence is the marked cyclonic circulation of the wind, lower and upper clouds, etc. This may be easily appreciated by remembering that a cyclone of any great intensity is an ascending spiral whirl, with a rotary motion (in the Northern Hemisphere) against the hands of a watch, as shown on the diagrams The surface wind, therefore, blows spirally inward (*not* circularly, except very near the center); the next upper current (carrying the low scud and rain clouds), in almost an exact circle about the center; the next higher current (the high cumulus), in an outward spiral—and so on, up to the highest cirrus clouds, which radiate directly outward. The angle of divergence between the successive currents is almost exactly two points of the compass. Ordinarily, with a surface wind from N., for instance, the low clouds come from N., also; on the edge of a hurricane, however, they come from N NE., *invariably*. In rear of a hurricane, the wind blows more nearly inward; with a SE. wind, for instance, the center will bear about W., the low clouds coming from S SE. (two points to the right of the wind), etc. Great activity of movement of the upper clouds, while the storm is still distant, indicates that the hurricane is of great violence. If the cirrus plumes that radiate from the distant storm are faint and opalescent in tint, fading gradually behind a slowly thickening haze or veil, the approaching storm is an old one, of large area; if of snowy whiteness, projected against a clear blue sky, it is a young cyclone of small area but great intensity.

Intensified Trade-wind Belt.—Another very important fact (established by Meldrum, at Mauritius) may be stated thus: When a hurricane is moving along the equatorial limits of a trade-wind region, there is a belt of intensified trades to windward of its track: not until the barometer has fallen about six-tenths of an inch it is safe to assume that, because the trade-wind increases in force and remains steady in direction, you are on the track of the storm. By attempting too early to cross its track, running free as soon as the wind begins to freshen, you are liable to plunge directly into the vortex of the hurricane.

General Information.—Hurricanes are especially liable to be encountered from July to October, inclusive, in the tropics (north of the 10th parallel), the Gulf of Mexico, and Gulf Stream region. Earliest indications: Barometer above the normal, with cool, very clear, pleasant weather; a long, low, ocean swell from the direction of the distant storm; light, feathery cirrus clouds, radiating from a point on the horizon where a whitish arc indicates the bearing of the center. Unmistakable signs: Falling barometer; halos about the sun and moon; increasing ocean swell; hot, moist weather, with light variable winds; deep red and violet tints at dawn and sunset; a heavy, mountainous cloud bank on the distant horizon; barometer falling more rapidly, with passing rain squalls.

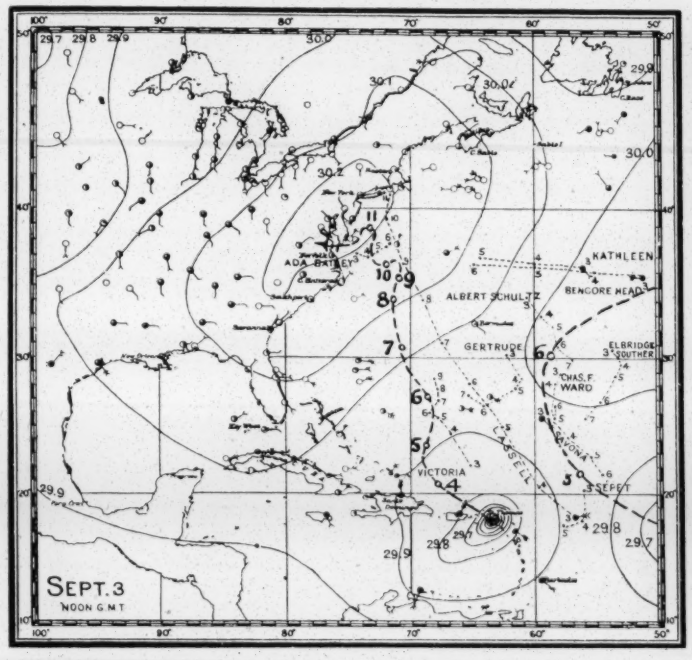
Brief Rules for Action.—If the squalls freshen without any shift of wind, you are on the storm track: run off with the wind on the starboard quarter and keep your compass course (see caution in paragraph entitled "Intensified Trade-wind Belt"). If the wind shift to the right, you are to the right of the storm track: put the ship on the starboard tack and make as much headway as possible, until obliged to lie-to. If the wind shift to the left, you are to the left of the storm track: bring the wind on the starboard quarter and keep your compass course; if obliged to lie-to, do so on the port tack. In scudding, always keep the wind well on the starboard quarter, in order to run out of the storm. Always lie-to on the coming-up tack. Use oil to prevent heavy seas from breaking on board.


SYMBOLS
WIND
calm
variable
N.E. force 4
W. " 6
S.W. " 8
E. " 12
WEATHER
: Rain
* Snow
▲ Hail
≡ Fog
∞ Haze
○ cloudless
⊕ ¼ covered &c.
● overcast
LIST OF VESSELS WHOSE POSITIONS ARE PLOTTED ON THIS CHART.
NAME.
POSITION.
Lat. Long.
*Allss (Lr. S. S.) 39.7° 74.5°
Alvo (Br. S. S.) 18.5 72.5
Alene (Br. S. S.) 37.1 74.2
Arab Steed (Swed. Bk.) 30.2 72.9
Arkona (Br. S. S.) 40.0 63.4
Armenia (Am. Sp.) 36.0 73.0
Barrowmore (Br. S. S.) 37.4 74.4
Barraconta (Br. S. S.) 31.6 73.5
Benito Estenger (Sp. S. S.) 19.9 75.8
*Blucher (Ger. Bk.) 37.8 69.7
British Princess (Br. S. S.) 43.4 50.6
Caribbean (Br. S. S.) 38.4 73.4
Caspian (Br. S. S.) 44.3 53.4
Catania (Ger. S. S.) 39.5 68.7
Cherokee (Am. S. S.) 34.0 76.4
Circassian (Br. S. S.) 47.9 51.8
City of San Antonio (Am. S. S.) 36.8 74.3
*Clarinet (Br. S. S.) 37.8 74.0
Colon (Br. S. S.) 31.5 74.2
Comet (Am. Sch.) 38.6 74.0
Constellation (U. S. S.) 36.6 53.8
Crown Prince (Br. S. S.) 41.3 49.8
Denmark (Br. S. S.) 40.4 71.1
Dorian (Br. S. S.) 31.4 75.7
Dryden (Br. S. S.) 27.0 68.3
E. C. Knight (Pilot-boat) 38.8 74.5
Eclipse (Am. Sp.) 30.4 58.7
Edam (Dutch S. S.) 43.0 62.0
*Effective (Br. S. S.) 37.4 68.4
Elbe (Ger. S. S.) 40.7 67.5
Elbridge Souther (Am. Sch.) 19.6 61.9
Emma C. Knowles (Am. Sch.) 39.7 70.7
Engineer (Br. S. S.) 39.3 73.9
Ethiopia (Br. S. S.) 40.6 70.0
Etruria (Br. S. S.) 40.9 66.7
Excelsior (Am. S. S.) 34.5 69.7
Exeter City (Br. S. S.) 40.5 66.8
Explorer (Br. S. S.) 27.7 79.7
Fanita (Am. S. S.) 36.8 75.0
Fort William (Br. S. S.) 31.6 79.1
France (Br. S. S.) 40.7 67.8
Frieda Grampp (Ger. Bk.) 37.6 69.1
Gedney (U. S. C. & G. S. S.) 18.4 64.9
Grecian (Br. S. S.) 39.9 74.0
H. B. Hussey (Am. Bg.) 31.0 78.3
H. C. Sibley (Am. Bg.) 34.5 69.9
Henry Hilliard (Am. Sp) 18.1 58.3
I. L. Skolfield (Am. Bk.) 17.8 70.4
Jamaican (Br. S. S.) 19.1 69.7
J. F. Loubat (Pilot-boat) 39.8 73.8
Kepler (Br. S. S.) 39.9 54.3
Kokoma (Br. Bk.) 30.7 69.7
Lady Lisgar (Br. Bk.) 37.2 67.7
Lampasas (Am. S. S.) 38.3 80.0
Letimbro (It. S. S.) 34.6 68.5
Lizzie Carter (Am. Bk.) 38.8 70.4
Lord Clive (Br. S. S.) 38.8 74.5
Lorenzo D. Baker (Am. S. S.) 18.2 76.4
Louisiana (Am. S. S.) 31.0 79.5
Luther A. Roby (Am. Sch.) 38.8 74.7
Maggie Abbott (Am. Sch.) 18.6 72.8
Manhattan (Am. S. S.) 34.5 80.0
Main (Ger. S. S.) 39.5 61.7
Marta Stoneman (Br. Bk.) 40.4 68.9
Marmion (Br. S. S.) 39.8 73.5
Martello (Br. S. S.) 40.3 71.7
Messenger (Am. Sch.) 39.8 75.0
*Miranda (Br. S. S.) 32.3 66.5
Monsita (Br. Bktn.) 31.9 74.8
Nedjid (Br. S. S.) 39.5 64.0
New York (Am. S. S.) 35.8 77.3
Oregon (Br. S. S.) 40.5 54.9
Polynesia (Ger. S. S.) 40.9 66.3
Pomona (Br. S. S.) 30.3 74.7
Prins Frederik Hendrik (Dutch S. S.) 39.2 74.1
Rhyaland (Belg. S. S.) 40.6 69.4
*Richmond (U. S. M. Light-house Tender) 38.5 72.8
Rio Grande (Am. S. S.) 39.0 74.0
Santiago (Am. S. S.) 34.9 77.8
S. B. Hubbard (Am. Sch.) 39.0 77.7
Scandinavian (Br. S. S.) 42.7 62.5
Scythia (Br. S. S.) 42.8 64.5
Sea Witch (Am. Sp.) 38.2 75.2
Servia (Br. Sp.) 38.2 63.2
State of Pennsylvania (Br. S. S.) 43.7 58.7
State of Texas (Am. S. S.) 33.4 77.8
Taria Topan (Am. Bk.) 16.2 55.6
Telefon (Nor. Sp.) 37.7 55.5
Trinidad (Br. S. S.) 34.6 66.7
Tropic (Br. S. S.) 39.9 74.9
Twilight (Br. Bgtn.) 18.0 63.1
Vancouver (Br. S. S.) 42.5 54.7
Venetian (Br. S. S.) 42.5 64.0
Venturer (Br. Bg.) 34.0 75.7
Werra (Ger. S. S.) 44.0 54.8
Winter Quarter Shoal Light-ship 38.0 75.1
Wyanoke (Am. S. S.) 38.9 75.9
* Data obtained by Interpolation.
THE HURRICANE OF NOVEMBER 25, 1888: NOON, G. M. T.
30.8
30.7
30.9
30.6
30.5
30.4
30.3
30.2
30.1
30.0
29.9
29.8
29.7
29.6
29.5
29.4
29.3
St. Johns
C. Race
Halifax
C. Sable
Sable I.
Boston
New York
Norfolk
C. Hatteras
Southport
Savannah
Bermudas
Key West
Havana
CUBA
Progreso
Mason
Santo Domingo
St. Thomas
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°

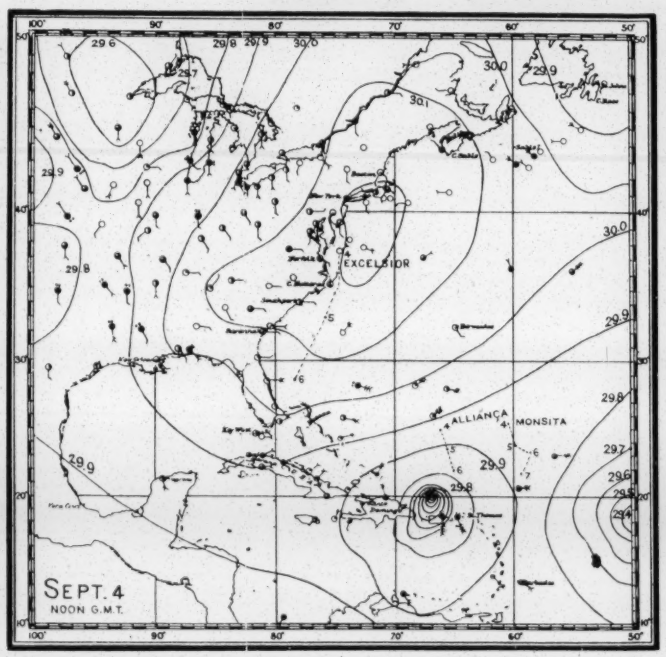
THE HURRICANE SEASON.—June may be fairly said to be the first of the five hurricane months in the North Atlantic, and the above diagram is presented in order to call special attention to the Law of Storms, especially to certain important modifications of the old laws. The spiral lines indicate the general wind-circulation in this particular hurricane, and the complete data presented on the Chart must convince any one that conclusions based upon such evidence must be worthy of the most careful consideration. This hurricane was one of the most severe on record off our Atlantic coast, and, though much larger than a hurricane in the tropics, similar evidence can be presented to show that the 8-point rule is seldom a safe guide for obtaining the bearing of the center; a 10-point or even a 12-point rule is generally better, although the 8-point rule is fairly correct if applied to the direction of the low clouds, rather than the wind. The long sweep of NE'ly winds along the coast, when there is a hurricane below Hatteras, is a very characteristic and important feature. With a NE'ly wind off Block Island, for instance, it should not be assumed that the center bears SE.: the Chart shows that it may be almost due south. There is likewise a wide region where the wind is from the SE., and a vessel running before this steady SE. wind would plunge deeper and deeper into the hurricane. Similarly in the trades, to windward of the track of a hurricane: not until the barometer has fallen about 6-tenths of an inch is it safe to assume that, because the trade-wind increases in force and remains steady in direction, you are on the track of the storm; by attempting too early to cross its track, running free as soon as the wind begins to freshen, you are liable to plunge directly into the vortex.

XUM

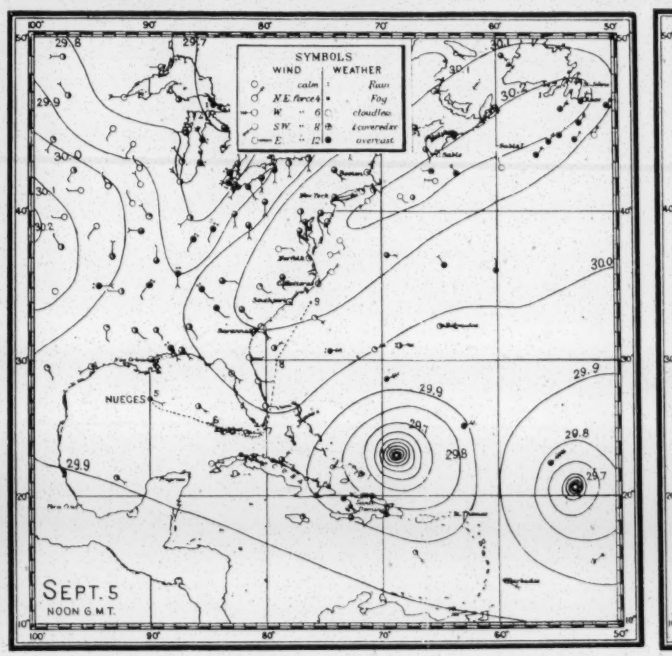
THE ST. THOMAS-HATTERAS HURRICANE OF SEPTEMBER 3-12,



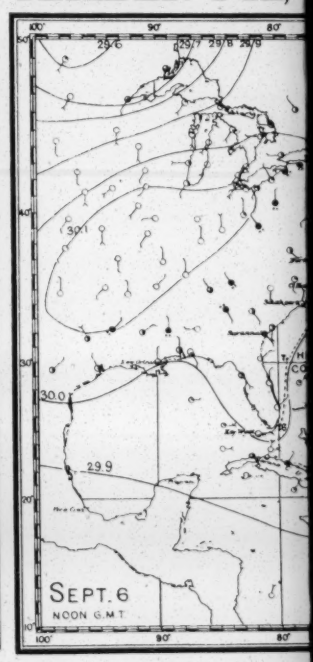
Sept. 3.—A hurricane of great intensity is passing close to the northward of St. Thomas, moving about W. NW. Lowest barometer at St. Thomas during the day, 28.97. Steepest observed barometric gradient (between St. Thomas and Puerto Rico), .75 inch in 65 miles. The cyclone is a large one, and of terrific energy,—an enormous whirlwind more than 500 miles in diameter, with a central calm area about 18 miles in diameter. It was experienced with destructive violence amongst the Windward Islands, from Martinique to Barbuda, on the 2d, and the vortex passed over St. Christopher's about midnight, the central calm lasting from 10.15 p. m. of the 2d till 12.45 a. m. of the 3d. There are evidences of another hurricane about 1,000 miles eastward of the first, moving about W. NW.



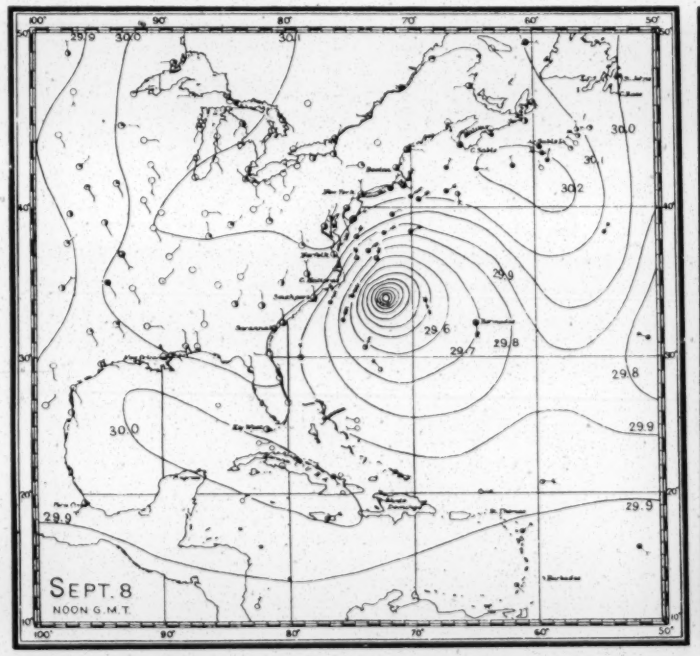
Sept. 4.—The hurricane is central north of Puerto Rico, where strong northerly, westerly, and southerly gales are experienced, but not of full hurricane force. During the forenoon its massive, towering cloud-bank is clearly visible from Turk's Island, 300 miles away, causing great alarm till it is seen to be moving well to the northward of the island. A violent storm in Santo Domingo this afternoon seems to be either an offshoot from the cyclone or the effect of another storm crossing the island to join the great hurricane—possibly a storm that was felt at Curaçao the previous day. The second hurricane has continued its motion toward W. NW. and its present position is clearly indicated about the eastern limits of the Chart.



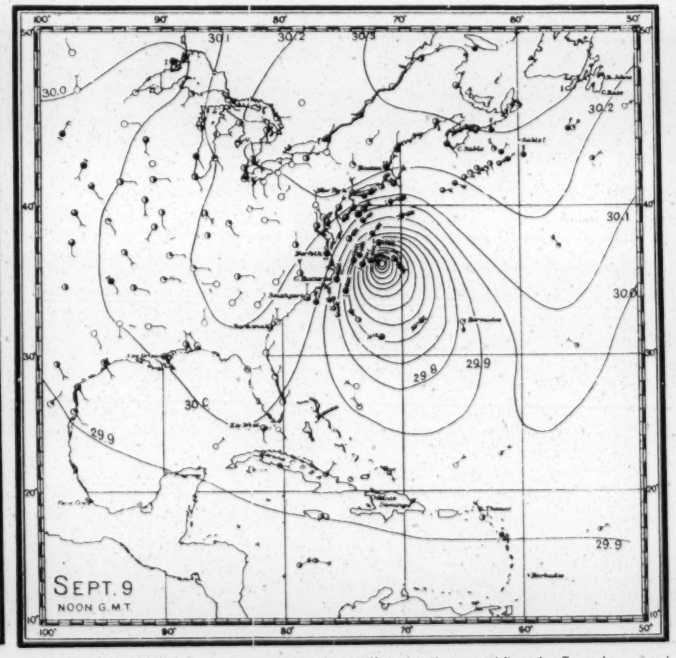
Sept. 5.—The hurricane is moving rather slowly along a northwesterly course toward Hatteras. The enormous seas started by the great whirlwind during its progress thus far have overspread almost the entire western half of the Atlantic: heavy northeasterly swell at Jamaica and through the Windward Channel; northeasterly and easterly, all along the Bahama Islands and northern Florida; very heavy surf at Bermuda; long rolling swell from S. SE., off Hatteras, perceptible as early as the 2d and increasing daily; long, low southerly swell off Nantucket as early as the 4th, when the storm-center was 1,300 miles away. The second hurricane is moving northwestward, and is beginning to recurve about 600 miles S. E. from Bermuda.



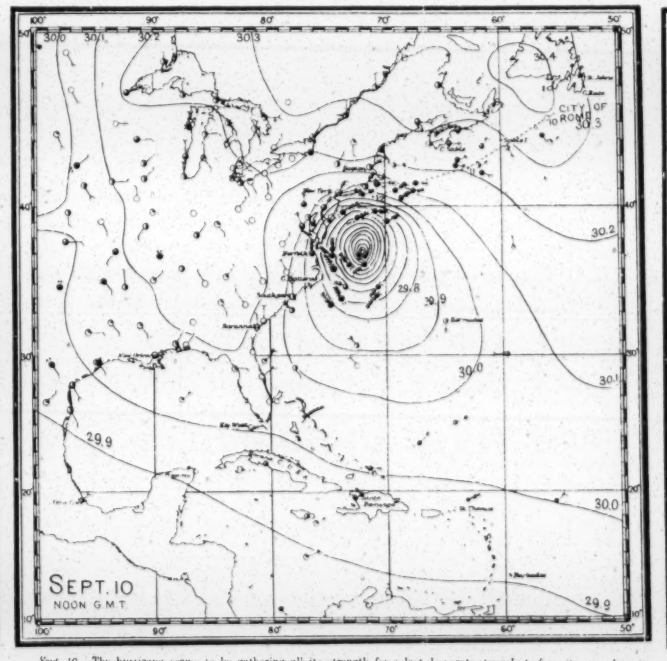
Sept. 6.—The concentric isobars on the Chart show t
Eastern Cuba, with barometric pressure at the center p
still exhibited, and to a marked degree: storm area no
velocities near the center; sudden shifts of the wind in t
the crests of the waves; sky of inky blackness, with m
and on either side, calm, sultry, hazy weather, with a tre
cloud-bank of the hurricane. A long ridge of high pres



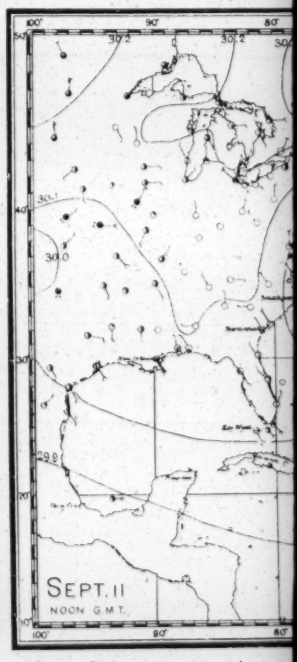
Sept. 8.—The hurricane is central about the axis of the Gulf Stream, off Hatteras. The area of high barometer in advance is retarding its northward progress, and preventing it from recurving to the northeastward. The heavy surf and the increased height of the tides, due to the storm-wave of the hurricane, begin to attract general attention and to cause damage along the low-lying portions of the coast between Norfolk and Newport; warm, moist ocean air is being driven in over the cold inshore current, and dense fogs are encountered off the coast north of the 35th parallel. The storm is losing a little of its tropical intensity, but its area is increasing and winds of hurricane force are raging over a vast area between Hatteras and Bermuda.



Sept. 9.—The storm is still raging with great violence between Nantucket, Hatteras, and Bermuda. Tremendous seas and tides are driving in on the coast. It is blowing with hurricane force close in shore near Hatteras. The storm-center is still moving northward, but more slowly, and the great area of high barometer into which the hurricane has forced its way stands fast, the pressure rising to 30.30 over the Gulf of St. Lawrence and the isobar of 30.00 reaching south on either side well down toward the tropics. To the northwestward, northward, and northeastward, close to the outer limits of the great whirlwind, warm, sultry weather prevails with calms or light, variable winds, hazy weather, and barometer above the normal.



Sept. 10.—The hurricane seems to be gathering all its strength for a last desperate struggle to force its way along its normal track to the northeast. The wind-arrows plotted on the Chart illustrate very graphically the marked circular character of the great whirlwind. The storm-wave, or general elevation of the oceanic surface caused by the in-rushing and whirling winds, and the reduced barometric pressure (acting as a partial vacuum), bank up the water in the bight of the coast about Sandy Hook, and cause the greatest floods on record at many places along the eastern coast of New Jersey and the southern shore of Long Island.



Sept. 11.—The barometric pressure at the storm-c
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and the cyclonic circulation is no longer so well marke
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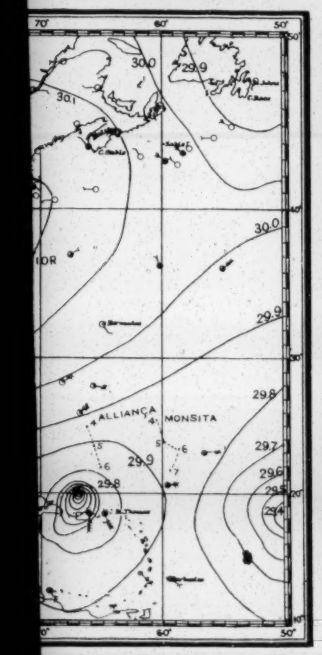
with the cold in-shore current, cause dense fogs and sq

ST. THOMAS-HATTERAS HURRICANE OF SEPTEMBER 3-12, 1889.



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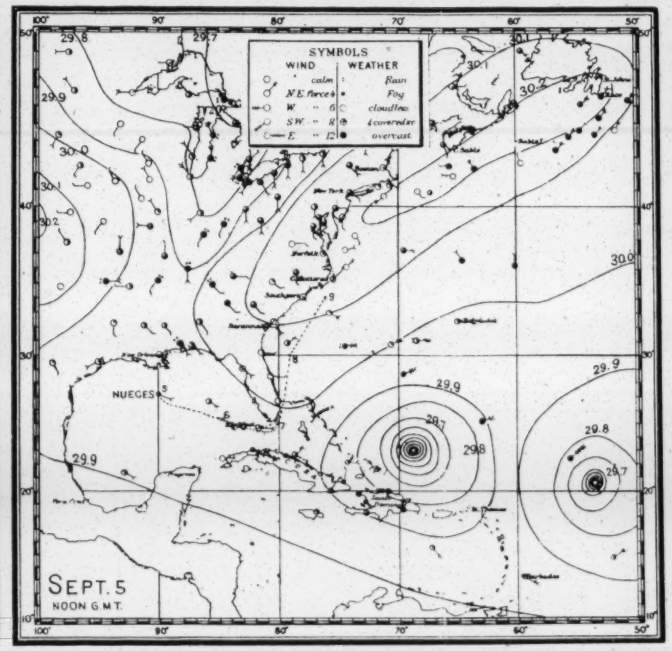

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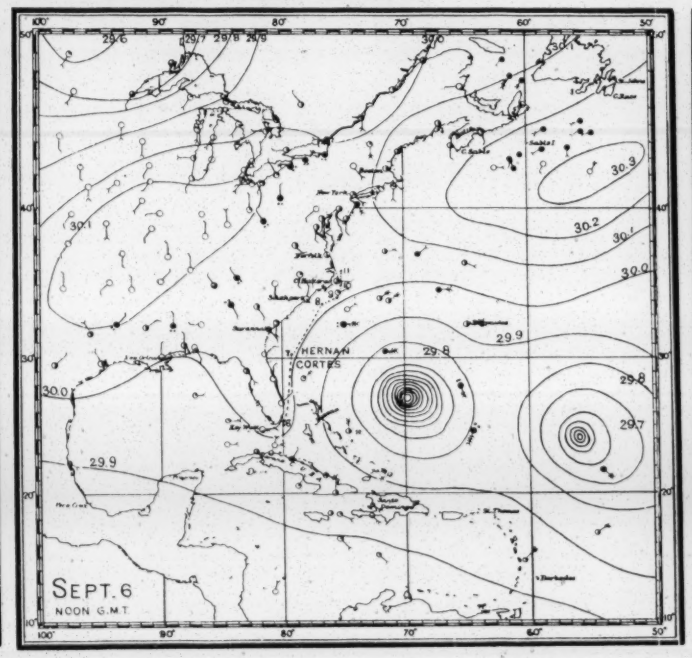
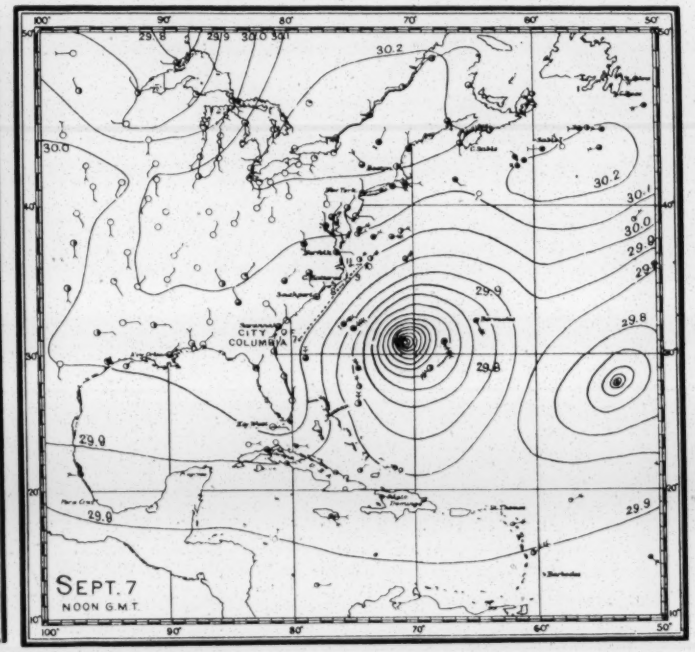
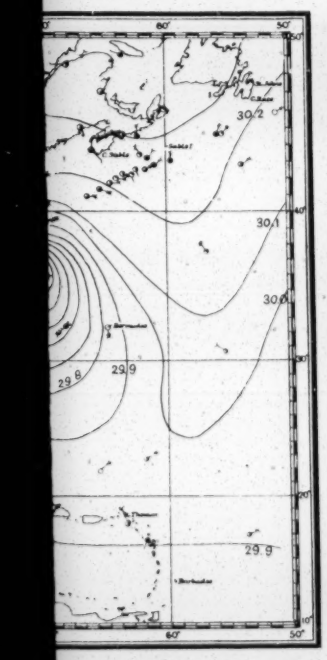


Sept. 6.—The concentric isobars on the Chart show that the hurricane is now central about midway between Bermuda and Eastern Cuba, with barometric pressure at the center probably below 28.40. All the characteristics of a tropical cyclone are still exhibited, and to a marked degree: storm area noticeably circular in outline; very steep gradients and enormous wind velocities near the center; sudden shifts of the wind in terrific squalls; heavy driving rain mingled with foam caught up from the crests of the waves; sky of inky blackness, with masses of flying scud so low as to touch the masts. Close by, in front, and on either side, calm, sultry, hazy weather, with a tremendous swell rolling in from the direction of the distant but massive cloud-bank of the hurricane. A long ridge of high pressure is building up to the northward of the hurricanes.



Sept. 7.—The hurricane continues its slow but steady march toward Hatteras. Yesterday morning the observer at Santiago de Cuba reported the cyclone recurving. This morning the meteorologist at Havana, 900 miles away, reports the cyclone's movements, guided by the motions of the upper clouds,—the cirrus veil that overspreads the entire sky with a thick haze, and the long feathery plumes of cirrus cloud that are faintly visible above it, radiating from the distant storm. The influence of the great hurricane begins to be felt along the outer edge of the Gulf Stream, below Hatteras. A heavy surf is rolling in on the coast all the way from Cape Florida to Block Island, and the long southerly swell has reached beyond Sable Island to Cape Breton. The second hurricane is moving N.Ed., and a ridge of high pressure is extending Sd. between the two.



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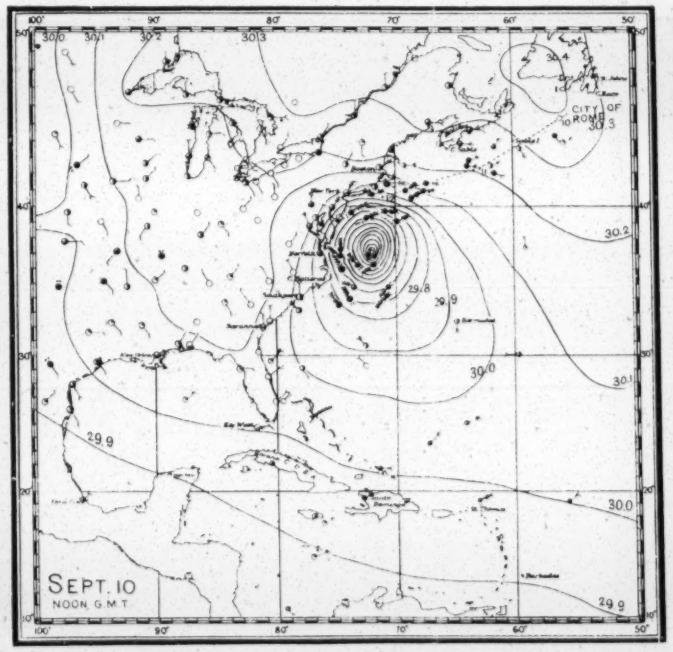

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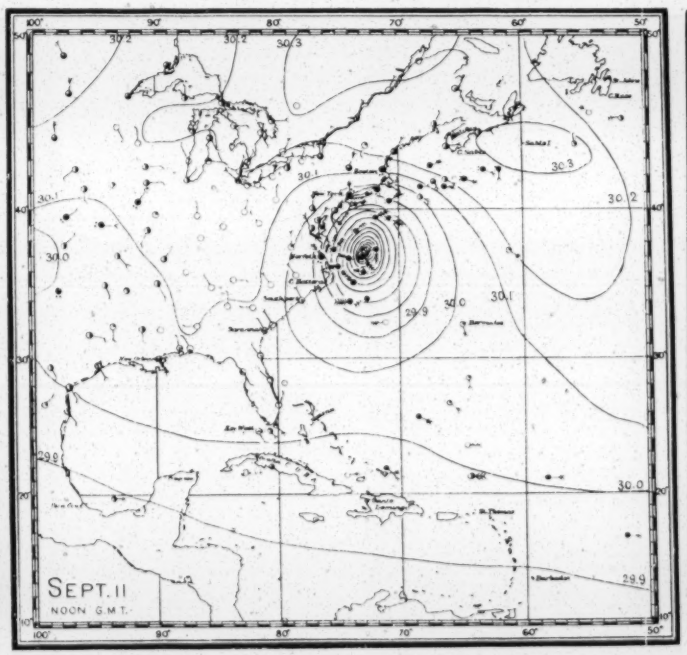
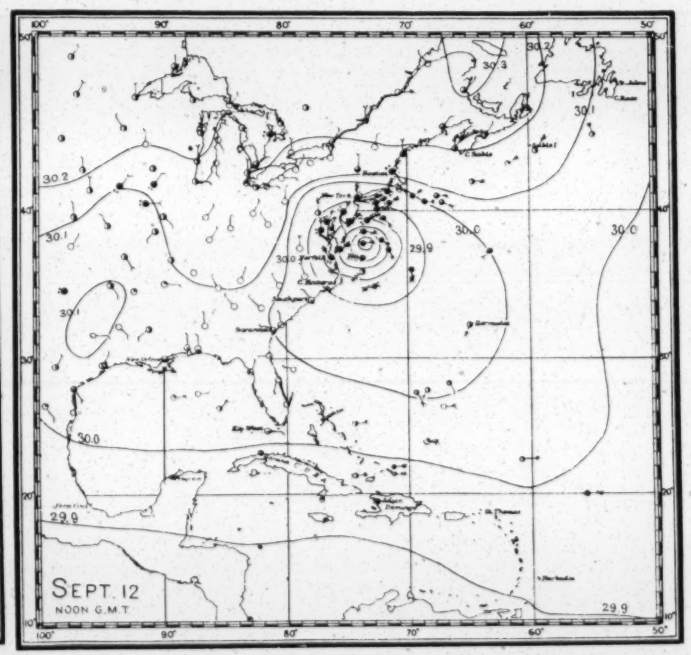


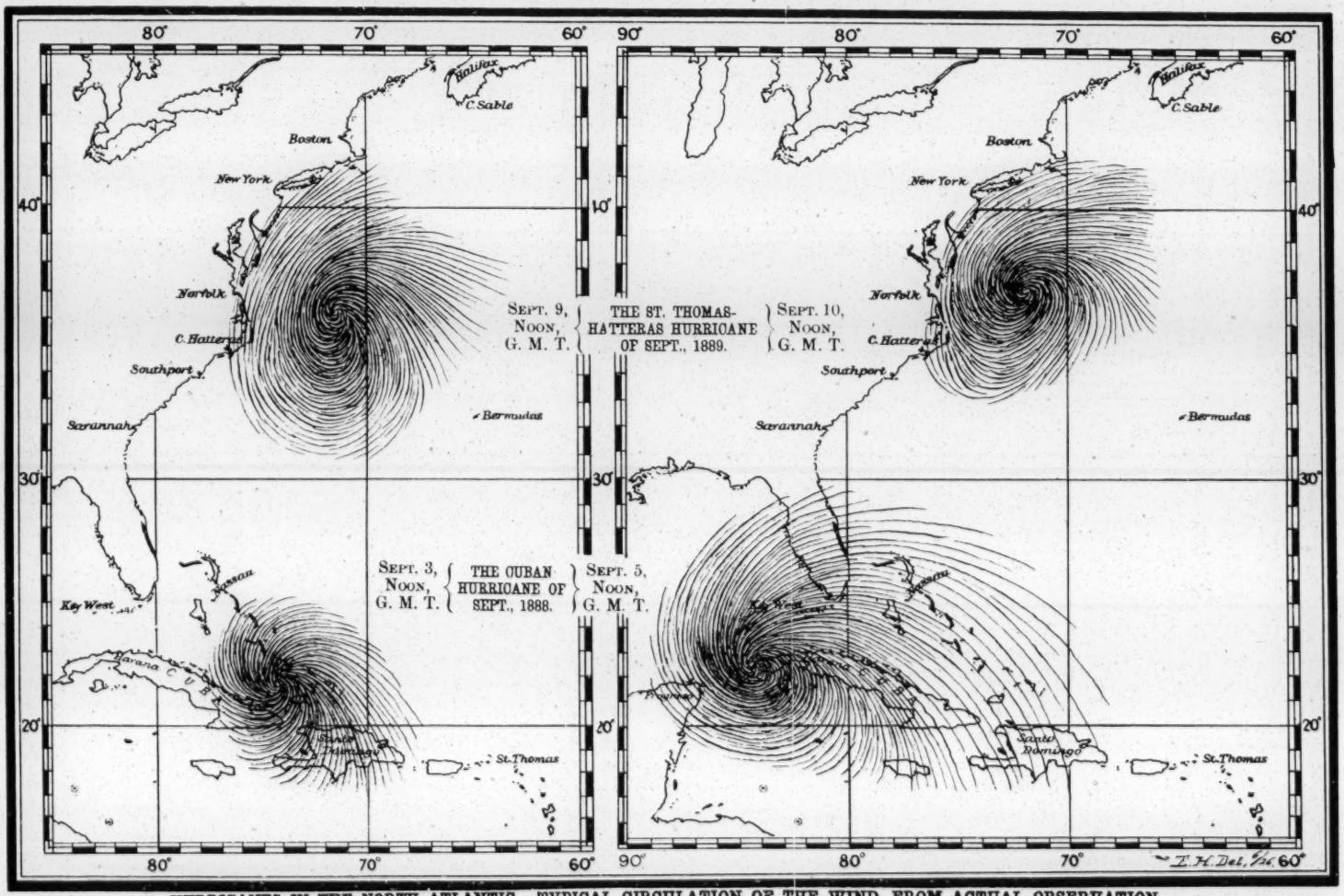
Sept. 11.—The barometric pressure at the storm-center has increased noticeably. The low area is filling up, and the barometric gradients are very much less steep. Very few winds of full hurricane force are reported. The storm-center has moved in toward shore, however, and stormy winds are still felt along the coast. The clouds are breaking away in places, and the cyclonic circulation is no longer so well marked. The warm waters of the Gulf Stream have been driven in toward the coast off Block Island by the long-continued and furious southeasterly gales to the right of the storm track, and, mingling with the cold in-shore current, cause dense fogs and squally, unsettled weather.



Sept. 12.—The great hurricane has blown itself out, and although a few reports still give a force of wind as high as 10 of Beaufort's scale, the storm has practically ended. Its remnants drift inland during the 13th and 14th, with cloudy, rainy weather in eastern Virginia and Maryland. It leaves a mountainous cross-sea that lasts for several days, a coast line strewn with wreckage, and already some twenty additions have been made to the list of derelicts and drifting wrecks whose positions are plotted on the Pilot Chart as a caution to navigators. How many vessels it wrecked at sea can never be fully known, but its entire track is marked by wrecks and wreckage.

XUM

[From the Pilot Chart of the North Atlantic Ocean, July, 1890.]



HURRICANES IN THE NORTH ATLANTIC.—TYPICAL CIRCULATION OF THE WIND, FROM ACTUAL OBSERVATION.

The above diagrams have been prepared from a large number of observations in order to illustrate the actual circulation of the wind in hurricanes, as a practical guide for navigators during the present hurricane season. The small chart that was presented on the Pilot Chart last month gave all the observations upon which the spiral lines were based for that particular hurricane (Nov. 25, 1888), and the same method has been followed here, only the observations themselves are omitted, for the sake of clearness. Perhaps the most important point to notice is that the surface wind blows in an inward spiral curve, and not circularly, except very near the center. The center therefore generally bears more than eight points to the right of the wind. Another very important point is the fact that although the 8-point rule is nearly true when the wind is anywhere from *North to South by way of West* (that is, generally speaking, in the navigable semicircle), it is liable to be a very poor guide when the wind is from any point in the first or second quadrant. With the wind from NE, for instance, the center may bear anywhere from South to SE.; with the wind East it may bear from SW. to South; and with the wind SE. it may bear SW., West, or even (in the tropics) W NW. Perhaps the best general rule is that the center bears about eight points to the right of the direction from which the low clouds come, or, what is practically the same thing, eight points to the right of the wind at the moment of a sudden shift in a heavy squall; after such a shift the wind will remain steady in direction for a time, but the center is meanwhile moving along and the angle of bearing changes until the next shift, when it goes again to eight points, and so on.

It will be noticed that the northernmost of these two hurricanes was moving very slowly during the two days selected for illustration: had it been moving faster, the in-draught (or departure from the circular direction) would no doubt have been somewhat less in advance and considerably greater in rear than what is indicated. It is exceptional also to find a storm in this region growing smaller, as this seems to have done on Sept. 10th: it died out altogether in a few days, instead of continuing its motion toward E NE., as is usually the case. In the tropics the usual progressive motion is about W. by N., and this, together with the steady increase in size, is well illustrated in the case of the Cuban hurricane; it should be noted, however, that the interval is here two days, and not one, as in the upper diagram.

Masters of vessels are earnestly requested to keep regular observations for this Office during the hurricane season, even if only position, wind, weather, and barometer, at noon, G. M. T., are noted. A single additional report often adds greatly to the completeness of the data used in preparing these diagrams.

trated by the report of the "Victoria," quoted above) is of interest in this connection. If I have succeeded in this, and thereby given a clearer idea to the casual reader or suggested a fertile train of thought to any physicist, I shall feel more than repaid for the effort.

I have thus attempted little more than to touch upon the practical side of this great question, and this in a popular way, to induce my readers to follow me to the end. The many other interesting questions that might be raised and discussed must here be left untouched. Our efforts in the Hydrographic Office must be primarily to help the navigator, and only secondarily to try to collect and publish facts for the scientist to study at his leisure. The causes of these terrific storms are of interest to us as they may help us to predict their coming, rather than for the proof of any theory, or the gratification of any pet idea. And if Science will but improve the Law of Storms, as practical men use it for the guidance of their vessels and the safety of the lives and cargoes intrusted to their care, it will be one more welcome proof that theory and practice go hand in hand.

THE IRRIGATION PROBLEM IN MONTANA.

By H. M. Wilson.

The development of the irrigation resources of a region under the supervision of the Government, requires study of the social and political conditions and of the industrial occupations of its inhabitants.

The determination of the best plan for the utilization of its waters and agricultural lands is a problem in irrigation engineering. The solution of this problem calls for an intimate knowledge not only of the best methods of construction, but also of the values of its various agricultural products and soils; for a knowledge of its rainfall, evaporation, and steam volumes and of the duty of water. It further requires such an understanding of the topography of the region as will enable the engineer to determine the area of the catchment basin of each stream, and to intelligently select sites for the construction of canals and storage reservoirs and to determine from what source of water supply each district may be best irrigated.

Experience and practice in various parts of the world have already proven that irrigation enterprises, undertaken on a large scale by private capital have seldom been remunerative investments, in fact, have frequently been financial failures. This is due to many causes among which may be mentioned the fact that, though all the irrigable land may be finally settled and the works made to do their highest duty, taxes must be paid for many years and considerable sums expended annually for maintenance before the entire amount of available water is utilized, and interest is realized on the whole expenditure.

Most of the successful irrigation enterprises undertaken in the United States owe their prosperity to the ownership and sale of lands under their canals. In order to secure a proper remuneration to the capital which provides the water, and an efficient water service to the farmer who uses it with justice to both interests, State legislation must fully define the rights and responsibilities of appropriators, the units and methods of measuring the flow of streams, granting the right of way and appointing proper officers to see that the various laws are enforced.

That irrigation enterprises will have great and rapid development in Montana in the near future will be readily perceived from the facts shown later on in this article, while I am fully convinced that it is now entering on that period. The histories of both California and Colorado have shown that great mining activity have brought to them a large population who were enabled to gain a livelihood by mining pursuits, while the demand for farm products created by the miners, caused these people to turn their attention to agriculture, which is now rapidly surpassing in money value the output of the mines.

In California in the "fifties" mining was the supreme and only occupation, to-day agriculture is her mainstay; in the early "seventies" the same was true of Colorado, and now agriculture is rapidly becoming her most important industry. While Montana is to-day in the van in mining resources and output, the time for the supremacy of agriculture within her borders has received an increased impetus by her recent accession to Statehood.

In Montana the irrigation problem presents some features which are scarcely encountered in any other country.

Usually irrigation is practiced in semi-tropic and desert regions where though water is scarce, the climate is such that a great variety of agricultural products usually of the better paying varieties can be raised, in consequence of which enormous sums may be spent in irrigation works, thus imposing a heavy tax per acre on the land for their construction, and still, such is the productiveness of these regions, that the lands will yield fair profits.

In Montana the reverse is the case, water is generally abundant though sufficiently inaccessible in the larger streams to require extensive works in order to render it available, while the land though equally abundant also, will owing to the climate admit of the cultivation only of the less profitable crops, mainly hay, grain and potatoes, in consequence of which the cost of construction of the irrigation works becomes a question of vital moment, since a tax of a few cents per acre one way or the other will render the pursuit of agriculture a success or a failure, and decide the fate of the irrigation enterprises.

It is probable that $10.00 per acre for a water right in perpetuity, or $2.00 per acre per annum for the use of water is the maximum charge which the crops will bear.

Agricultural and Mineral Resources.

It will be advisable now to take a hasty glance at the State of Montana, and see what are her agricultural capabilities and what need exists for irrigation as a factor in their development.

According to the report of the State Auditor for 1888 there were in that year 143,700 horses and mules valued at $4,900,000; 488,500 cattle valued at $9,060,000; 1,153,000 sheep valued at $2,165,000; 3,741,000 acres of improved lands, valued inclusive of improvements at $12,300,000; 55,000 town lots valued with improvements at $14,940,000; and including all kinds of personal and real property a total assessment for the State of $67,500,000.

There were raised in the State during the same year 770,000 bushels of wheat on 26,000 acres, an average yield of about 30 bushels per acre; 3,000,000 bushels of oats on 85,000 acres, an average yield of over 35 bushels per acre; 843,000 bushels of potatoes on 3700 acres, or 230 bushels per acre; and 6,000,000 lbs. of all other vegetables on 450 acres; 235,000 tons of hay were cut, and 7,500 bushels of apples and other fruits were raised, while 4,500,000 lbs. of wool were sheared.

The gross receipt of the quartz mills were $20,300,000, the value of the product of the reduction furnaces was $15,900,000 in bullion, and the coal mines produced 500,000 bushels of coal.

The wool product for the present year, 1889, exceeded in amount that of any other State west of the Missouri River, and its quality was such that it brought a higher price per pound than that of any other western State, the price paid in California ranging from 15 to 17 cents per pound against 20 to 23 cents paid in Montana.

The accompanying table will show the relative value of the production of precious metals in the three leading States during 1887, from which it will be seen that Montana led Colorado by $4,200,000, and California by $15,580,000.

1887.	Montana.	Colorado.	California.
Silver	$15,500,000	$15,000,000	$1,500,000
Gold	5,230,000	4,000,000	13,000,000
Copper	8,970,000	400,000	180,000
Lead	630,000	6,730,000	70,000
Totals	$30,330,000	$26,130,000	$14,750,000

Since 1887 Montana has been rapidly gaining in its lead, especially in the production of copper, and it now leads not only in

the total value of the precious metals produced, but also in the values of the silver and copper products separately, and is only surpassed by California in the production of gold.

While as shown above Montana produces large quantities of vegetables and grain, its heavy mining population and vast herds of live stock furnish a home market for all of its present product, in fact, during this year many hundreds of tons of hay and carloads of grain are being imported from the eastern States to feed the range stock during the coming winter.

Topography.

The topography of Montana is very different from what is generally supposed by those who are not familiar with it, and this erroneous impression is largely due to the fact that the country is very mountainous in the older inhabited and better known portion of the State, which lies in its southern corner near the Idaho and Wyoming lines; this region was first inhabited by those pioneers of western civilization, the prospector and miner, and in consequence of this and of the wild grandeur of the Yellowstone National Park, the generally preconceived notions of the topography and resources of the State are of forests and streams teeming with game and fish, and rugged mountains occupied by a few isolated mining camps and cattle ranches.

On the contrary there are scattered over various parts of the State many large towns, two of which, Butte and Helena, have each about 20,000 inhabitants, while only one-fourth of the area of the State is over 5,000 feet in altitude, and at least two-thirds of it is below 4,000 feet.

The mountainous district of the State, which occupies but two-fifths of the total area, is in the southwestern portion; these mountains are in fact but the last remnants of the great rockies breaking down from Wyoming and Idaho and terminating in the broad flat plains of the Saskatchewan River on the north, and of the Missouri River on the north and east.

It is in these great mountain ranges that the Clarke's Fork and Snake Rivers, two of the principal branches of the Columbia, after rising in the western and southern portions of the State join the Columbia on its way to the Pacific Ocean; among these mountains in the northern portion of the State the Saskatchewan River rises and flows thence to the Arctic Ocean; while the

great Missouri and one of its principal branches, the Yellowstone River, rise in these mountains and after flowing northward nearly to the British line turn and flow eastward and join the Mississippi on its way to the Atlantic.

The highest mountains in Montana are in Park, Gallatiin, Madison and Beaver Head Counties, in which latter the furthermost branches of the Missouri, the Beaver Head and Big Hole Rivers, which form the Jefferson river, have their sources at the summit of the Rocky mountains, and it was here that those intrepid explorers, Lewis and Clarke, first crossed the Continental Divide in 1805 to the headwaters of one of the branches of the Snake river.

In these counties a few of the highest peaks reach an elevation of 11,000 feet, and from here the main range of the Rockies bears off to the north in a long, continuous and rugged ridge of sandstone and porphyry, with extensive beds of limestone north of the headwaters of the Dearborn River, and gradually falling off in elevation, until near the British line the highest peaks are less than 7,000 feet above the sea.

From this same axial point in the southwest corner a main spur or branch of the Rockies, called the Bitter Root Mountains, bears northwesterly and falling away in height, gives out with an elevation of 2,200 feet in northern Missoula County where the Clarke's Fork river leaves the State, cutting across the foot of this range.

East of Madison and Jefferson Counties, and along the southern border of the State, are numerous short mountain ranges, often 10,000 feet and sometimes 11,000 feet in elevation, which have generally a north and south trend and fall off near the middle of the State to a continuous, broad, and nearly level high prairie, or as it is locally called "bench land," which continues to fall slowly in the same direction.

Do not imagine that these great ranges of mountains are wild and uninhabited for such is not the case ; they are merely great mountain masses, and between, among and on top of them are other minor ranges of mountains, usually having symmetrical and regularly sloping sides, which are separated by broad, level and very fertile valleys, everywhere inhabited and cultivated by the aid of irrigation, while herds of cattle, horses and sheep graze on the hillsides.

Even among the roughest mountains a man may travel alone on horseback sure of finding shelter and food somewhere in the

course of a day's journey, as was done by the author during the past summer, when he rode over 2,000 miles in various parts of the State. In the more rugged places mining camps may be met with when everything else fails.

At present these mountain valleys are the more thickly inhabited portions of the country, both because of the mines and because farming pursuits are more cheaply and conveniently followed owing to the greater abundance of small and easily controlled streams of water, which render irrigation possible even by the poorest settler. Only in the southern portions of Gallatin and Park Counties are the mountains so forbidding as to be uninhabited, and then in limited areas only.

One of the remarkable characteristics of the Montana mountains is their great regularity and smoothness of contour. It is probable that ice action during the glacial period may have planed off the irregularities, so characteristic of the elsewhere rugged outline of the Rocky Mountains. Between these symmetrical ranges of mountains lie the broad and fertile valleys before referred to. These are generally valleys of construction, and in some former geologic period were occupied by lakes whose beds have since been drained by the streams, as they cut their way out of the mountains.

It is the extensive deposits from the ancient lakes which give to these valleys their fertile soils, while the unusual mildness of their climate is largely due to the fact that they are seldom over 5,000 feet in altitude, and the high mountains surrounding them shelter them from the severe winds which, sweeping over the plains of Dakota, become the much dreaded "blizzards."

East of the Tongue River and north of the Yellowstone and Missouri Rivers, the level bench lands are everywhere below 3,500 feet in elevation, and often below 2,500 feet, and are very dry and devoid of water, though covered by an abundant growth of fine bunch grass. These bench lands are traversed by a few narrow, deep "couleés" or "washes" having bluff banks 50 to 300 feet high, dry during most of the year, though roaring torrents in the early spring months.

It is on these bench lands that irrigation will find its greatest field, for here is a comparatively mild climate owing to the low altitude, and here the soil is fertile, warm and deep.

Area and Kinds of Lands.

The total area of Montana is 146,080 square miles, or 93,491,200 acres. Of this vast empire 31,373,000 acres or about one-third of the whole is agricultural land, while of this 18,157,000 acres or a little less than one-fifth of the entire area is irrigable land, so classified not only because it will, if provided with water, raise profitable crops, but also because, in my opinion, water can with proper management be provided for it.

Of the total area of the State only about 1,200,000 acres or less than one-sixteenth of the irrigable area may be easily cultivated, by this I do not mean that this whole amount is now reclaimed, but that it may with the means liable to be employed by private parties with limited capital, be readily brought under cultivation by the same methods by which most of the lands in Montana are now irrigated.

The amount of land actually under cultivation, according to the assessment of 1888, was 348,070 acres, and this should probably be increased by about one-half, since the farmers doubtless greatly underestimated the amounts of their cultivated lands to the assessor: perhaps then, 500,000 acres under cultivation would be nearer the truth.

It is estimated that three-fourths of the remaining 75,000,000 acres not classed above as irrigable, or say 55,000,000 acres, which is nearly two-thirds of the total area of the State, will, with the increased facilities for watering live stock and for domestic use offered by the highest state of irrigation development, become valuable as grazing land, since it is naturally covered with an abundant growth of bunch grass, and only needs better facilities for watering and for the establishment of home farms, to cause it to be entirely occupied for grazing purposes.

Nearly, or quite all, of the lands above classified as agricultural and pasture lands, are now covered with an abundant growth of bunch grass, occasional patches of sage brush or prickly pear, and devoid of any timber other than patches of willows and cottonwoods along the streams, or a few isolated clumps of scrub pines and junipers on the highest lands.

About 10,000,000 of the remaining 20,000,000 acres are excellent timber lands and are situated on the slopes and sides of the higher mountains, though west of the Continental Divide the valleys and flat bench lands are sometimes covered with timber.

The remaining 10,000,000 acres may be classed as barren and rugged mountain peaks and some little barren "bad lands" near the southeastern corner of the State, and the broken and rough cut banks of rivers, "couleés," etc.

It is in these more rugged mountain regions that the great gold, silver and copper deposits are found.

Climate.

The climate of Montana is far more moderate and agreeable than is generally supposed, the spring and fall months in the valleys, which are the principal inhabited and cultivated portions, being delightfully mild and pleasant, with frost generally only at night, though these last till May and begin in early October.

The accompanying table shows the dates of the first and last killing frosts at Helena, also the mean monthly temperature at Helena, which place is chosen as a typical station, its altitude being 4,262 feet. From this table, which extends over a period of ten years, from 1880 to 1889, inclusive, with few interruptions, it appears that the earliest killing frost occurred on September 6th, 1881, and the latest killing frost on May 3d, 1888, but these were very exceptional frosts, the average dates for the same periods being September 26th and April 26th. The maximum temperature during the same period occurred in July, 1886, and was 103 degrees in the shade, while no other year showed a higher temperature than 97 degrees; and the average maximum temperature for the ten years was 94 degrees. The minimum temperature for the same period was –40 degrees, occurring in February, 1887, while the average minimum for ten years was –29 degrees. Great ranges of temperature are sometimes experienced, however, especially in local areas in the higher mountain valleys, where unusual frosts and snow flurries have occurred, though rarely, killing potatoes and other tender crops even in July and August.

On September 5th of this year in the upper Madison Valley above 6500 feet of elevation, a temperature was experienced in the forenoon of 70 degrees, while at about 8 o'clock on the same evening, a snow squall occurred during which the thermometer must have fallen several degrees below the freezing point; by 9 o'clock on the following morning all of the snow had disappeared and the temperature had greatly moderated.

The summer months in these mountain valleys are always agreeably warm during the day time, while the nights are cool and pleasant. In the winter the climate is very cold, though not so uncomfortable as the temperature would indicate, owing to the

Monthly Mean Temperatures at Helena, Mont.

	1880.		1881.		1882.		1883.		1884.		1885.		1886.		1887.		1888.		1889.	
	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.	Mean Temp.	Killing Frost.
January			9.8		20.0		18.5		11.6		21.0		10.1		20.6		5.3		16.7	
February			25.8		24.4		14.1		14.6		28.2		34.5		5.0		35.0		25.2	
March			39.4		31.1		34.2		29.1		40.6		29.1		40.3		23.2		39.1	
April			47.6		40.5		40.4		41.6		45.7		42.9		42.4	20th	48·8		49.2	
May			55.4		50.4		49.8		53.9		51.0		54.9		51.5		50.1		53.2	
June			61.4		60.7		61.8		62.9		56.8		61.1		57.6		58.8		63.4	
July		66.3	68.3		66.8		67.9		62.5		64.7		69.9		66.6		67.1		66.8	
August		63.7	66.1		71.4		67.2		66.8		64.1		68.1		63.0		65.3		67.2	
September		56.7	54.6	6th	60.1	29th	59.2	20th	49.7	6th	55.4		52.9	29th	56.0		61.2		55.2	
October		46.3	37.9	22d	41.7		38.9		47.0		47.5		43.3		42.9	8th	46.6		50.7	
November		19.3	28.8		30.9		33.0		36.4		39.1		29.4		33.9		24.2		31.4	
December		9.0	30.8		27.3		27.4		7.0		31.1		27.1		23.0		23.6		22.6	
Mean, Annual			43.8		43.8		42.7		40.3		43.6		43.8		41.9		42.1		45.0	

dryness of the atmosphere and the absence of very high winds in the mountain valleys. The more exposed plains to the north are subject to the frequent and agreeable visits of the famous "Chinook" winds, which blow from the west, and under whose influence heavy falls of snow disappear in a single day.

The following table shows the mean annual rain-fall at various Signal Service stations in Montana, and from these it will be seen that during a period of ten years the maximum rain-fall for the entire State has only been 20.33 inches in 1880, while the minimum has occurred during 1886 and was but 12.52 inches; the average precipitation for this period was 15.25 inches.

Mean Precipitation in Montana during Growing Season.

	Ft. Assinaboine.	Ft. Benton.	Ft. Buford, N. D.	Ft. Custer.	Ft. Keogh.	Helena.	Ft. Maginnis.	Ft. Missoula.	Poplar River.	Ft. Shaw.	Average.
Growing season of '80		7.33	12.82	9.77	8.87	2.63					8.28
" " " '81		7.05	5.81	3.90	5.67	7.15		3.70		5.78	5.58
" " " '82	4.47	1.29	5.01		3.64	1.96		2.78		4.23	3.00
" " " '83	2.63	4.25	3.94				2.27		1.65	4.17	3.16
" " " '84	17.22	5.69	3.46	6.31		8.09	2.90		5.80	4.30	6.72
" " " '85		9.57	10.33	6,07		6.29	5.98		7.14	6.49	7.41
" " " '86	2.52	2.94	2.65	5.13		1.91	3.56		2.67	2.87	3.03
" " " '87	12.13		8.00	2.96		5.88	9.47		8.67		7.85
" " " '88	7.10		10.16	8.22	7.28	4.37	10.54		8.16		7.98
" " " '89	5.03		3.48	2.90	2.27	2.00	7.47	1.74	2.23	1.91	3.23
	7.21	5.45	6.57	5.66	5.55	4.48	6.03	2.74	5.19	4.25	5.23

Growing season, May 15 to August 15.

Annual Rainfall in Montana, 1880–1888.

	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.
Ft. Assinaboine			12.76	15.10	25.67		11.48	18.94	13.99
Ft. Benton	16.00	16.81	10.18	13.01	13.13	14.94			14.00
Ft. Buford, N. D.	23.25	13.90	12.73	10.82	7.37	15.56	10.24	15.43	14.70
Ft. Custer	19.65	11.88			16.60	9.34	13.25	12.18	14.00
Ft. Keogh	15.64	11.44	10.13						
Helena		19.94	10.32		19.18	10.99	12.63	14.05	10.14
Ft. Maginnis				13.29	9.00	13.96	15.44	26.00	25.70
Ft. Missoula		20.56	13.24						
Poplar River						10.25	11.93	7.41	15.51
Ft. Shaw			14.77	14.21	12.64	13.64	12.56		
Ft. Ellis	30.16	17.55	19.28	15.72	22.02	32.63			
Virginia City	17.29								
	20.30	16.01	12.93	13.69	15.73	15.41	12.79	15.67	15.45

Moreover, from the first table, showing the average monthly precipitation at the Helena station, it will be seen that but 4.48 inches fall during May 15th to August 15th, inclusive, which is the growing season when the crops require moisture.

The information regarding evaporation is as yet very meagre, but from four stations observed in different parts of the State during August, September and October, it appears that the total average evaporation for the three months was 18 inches, and from the best information obtainable it appears that the total annual evaporation is 36 inches, that is to say, the surface of the water in a lake or reservoir will be lowered by evaporation 3 feet in a year.

Why Montana is an Arid Country.

It has been stated by Major J. W. Powell, that in a general way the line between the humid and arid regions, or the amount of precipitation below which irrigation becomes necessary for the cultivation of crops, is from 24 to 28 inches per annum. This of course depends largely on the distribution of the rainfall, the proportion falling during the growing season, the humidity of the atmosphere, the character of the soil, etc.

The average annual precipitation in Montana is 14.92 inches, while the total average precipitation during the growing season is but 5.23 inches; from these considerations alone it is evident that the State lies wholly in the arid region.

This statement is further born out by the fact that no native farmer will settle a ranch or undertake to raise any kind of crops without facilities for irrigating, since experience has taught them all, that, though there may occasionally be an exceptionally wet season in which they can raise good crops without artificial aid, still, the years when crops depending wholly upon rain-fall for their moisture would be entirely lost, are so frequent as to render farming without irrigation very hazardous and unprofitable.

Soil.

The soil along the stream bottoms at a slight elevation above their beds is usually a heavy, black, clayey loam, and though rich and fertile is soon clogged by water, and then in drying, cakes on the surface, killing the young plants. On this account the irrigators seldom water these bottom lands until after the crop has acquired a healthy growth, preferring to trust to the early rains

to force the young sprouts above the surface, rather than run the risk of its crusting and thus preventing them from breaking through.

These bottom lands though really the poorest for irrigating, are nearly the only lands now cultivated, because of the greater ease and cheapness of supplying them with water. From two to three tons of hay and from 35 to 50 bushels of grain per acre are raised even on these inferior soils.

The best, and by far the more abundant agricultural lands, are the "bench lands," these are situated high above the stream beds and the soil is usually a warm open, rich, sandy-loam, several feet in depth and usually underlain by a deep bed of gravel. Though in irrigating, this soil at first requires more water, it will, owing to its excellent natural drainage, last for all time and will neither clog with water nor cake on the surface.

It is these bench lands which will be rendered irrigable by government aid and surveys, though to develop them will require large amounts of capital; still, they are so extensive in area that the work can generally be conducted on a grand and economical scale.

Duty of Water.

From the meagre information now obtainable it is probable that in average soils and for the staple hay, grain and vegetable crops in Montana, about one cubic foot of water per second, flowing during the irrigating season, will be sufficient for 100 acres; this quantity is known as the "duty of water."

The irrigating season lasts about three months. While the crops are maturing during part of May, June and July, they will receive two or three waterings, and in early September the hay lands are again watered in order to start the growth of grass before the frosts.

In case all the surplus water of a given stream is stored, the duty of that stream will be increased by the amount of water now flowing to waste during the remaining nine months, and as a portion of this time is the flood period, owing to the melting of the snows in the mountains and to the spring rains, this storage water will increase the duty of the stream at least five-fold; that is, five times as many acres may be irrigated by the stream as at present, provided that storage capacity can be found for all of its waste waters.

In considering the duty of a stream it must be remembered that there is a great loss of water by seepage through the sides of a canal and evaporation from its surface, between the headworks and the irrigated lands, this loss may amount to from 25 to 35 per cent., according to climate, soil, and the length and cross-section of the canal.

Present State of Irrigation—Progress and Laws.

The earlier stages of irrigation development are better illustrated in Montana than in any other State in the Union.

There irrigation practice and laws are exceedingly crude and remain so chiefly because of the abundance of water, and the ease and facility with which it can be diverted to the land; as a consequence of this latter fact the laws were framed in the most liberal spirit, declaring right of eminent domain, acknowledging the right of priority in appropriating the waters, and further stating, that any person having a ditch leading to irrigable lands may use the waters of the territory for irrigation.

The latest law, framed in 1885, is a very slight improvement; it requires persons appropriating water, to post the usual notice in a conspicuous place; to file with the county recorder a notice of appropriation, with names and proper description of place, stream, etc., and that work must be commenced within forty days of the posting of the notice and be prosecuted with due diligence until completed.

Persons who have heretofore acquired title to the use of water, may within six months from the passage of this law file a statement of the above facts in the office of the recorder, but failure to do this shall not forfeit his rights.

Provision is made for the measurement of water, using that very uncertain and elastic unit, the miner's inch, and defining the same.

The difficulties arising under these laws will be appreciated, when I state that it is impossible to construct a rating flume that will measure the number of inches of water flowing in a large stream, by the method provided in the law.

Then, because previous appropriators are not compelled to record the amount of water appropriated, and those acquiring titles under the first law now invariably claim much more water than they need, in fact often appropriate and even record more water than there is flowing in the stream. This is owing to the fact that

they were not at first compelled to construct their works, "with due diligence until completed," nor to make ditches of capacities capable of carrying the volumes claimed, and above all because there is no officer having the power to measure the quantities of water diverted or to see that the works are prosecuted with due diligence. Endless and unsatisfactory litigation results, hastened by the occupation of lands lower down on some stream which in a very dry season may not flow sufficient water for all the appropriators who have acquired titles, whereupon the later settlers who have recorded their appropriations claim the water, while those who diverted water before the passage of the last law claim the right to it, though unrecorded, and as a consequence the case is carried to the courts, often with unjust and always with expensive results.

During the past exceptionally dry season these conditions led to much bitter litigation, often to bloodshed, and equally often to financial ruin owing to the supply of water being insufficient to mature the crops planted.

Water being very abundant in the smaller mountain valleys has led to great wastefulness in its use, the irrigator after applying what water his crops needed, instead of turning it back into the stream for the use of settlers lower down, generally turns his ditch loose on the open prairie and allows the water to run to waste. Then wasteful methods of applying the water to the crops are employed, and owing to the cheap and hasty construction of a vast number of small ditches the loss by seepage is very great; it has been estimated that there is on an average a ditch for every 200 acres of land cultivated, making a total of about 2500 irrigating ditches in the State.

In the last two years there has been a marked increase in the interest taken in irrigation enterprises, and though this has resulted in the formation of several large companies, which intend to take water by long and expensive canals to sections now uncultivated, yet in these cases are universally seen the same crude methods employed in first beginnings, without the aid and advice of experienced engineers. Large canals are being constructed at great cost, capable of carrying many times the amount of water flowing in the stream appropriated, whereas a much smaller and less expensive one would have carried the entire water supply. Again small canals have been constructed to carry small volumes of water very long distances, often 50 to 80 miles, while in

reality owing to the great percentage of loss by seepage and evaporation, little or none of the water entering at the headgates will ever reach the irrigable lands.

Such illy advised projects are to be even more deplored than the smaller operations before spoken of, since the certain ultimate failure of this class of enterprise will result in discouraging capitalists from investing in even well-planned irrigation projects, and will retard the construction of valuable and necessary works.

Possible Irrigation Enterprises.

During the past season the author made an extensive though hurried reconnoisance of Montana, in the progress of which he rode on horseback 2,200 miles and traveled 3,700 miles by rail, examining with some degree of detail all of the central counties and making a few hasty trips into Choteau, Dawson and Custer Counties. In the course of this reconnoisance the sites for sixty storage reservoirs, having a combined storage capacity of about 3,250,000 acre feet were carefully examined, and lines of ten great irrigating canals approximately decided on. It may be well to state here that an acre-foot of water is a very convenient unit of measure adopted by the U. S. Geological Survey in speaking of the contents of large reservoirs, and refers to a body of water one acre in superficial area and one foot in depth.

In every case these proposed reservoirs are so situated, that their storage water will be convenient to large bodies of irrigable land, which, without some such provision for water supply must forever remain uncultivated, but which with irrigation from these reservoirs will ultimately become thickly inhabited and very productive regions. The same statements apply to the canals projected, though of course detailed surveys may prove the impracticability of some of these works as financial investments.

Mention will be made of a few of the more important of these projects ; those which appear most likely to prove financial successes.

North of the Yellowstone and between it and the Musselshell and Missouri Rivers is an immense high bench land, traversed by a few long couleés, dry excepting in the times of melting snow or heavy spring storms, and then raging torrents for a period of a few days or hours. This bench land between the couleés is flat topped and has a regular and gentle slope to the eastward,

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falling about six feet per mile, a little more rapidly north of Big Timber, and decreasing in grade to the eastward. The general elevation of this bench above the Yellowstone River varies from 600 feet north of Stillwater, to 300 feet north of Miles City, and includes about 11,000,000 acres, of which at least 5,225,000 acres are of the best quality for agricultural purposes and readily accessible by the great canal. In all this vast area there is not even sufficient water for the few horses and cattle which range on it, and they are compelled to congregate near the occasional pools and springs scattered at long intervals over it.

From numerous examinations made hastily with aneroid and hand-level, it seems likely that a great canal can be taken from the Yellowstone, somewhere in the neighborhood of Livingston, or lower down the river, and led upon the summit of the bench with a diversion line not over 100 miles in length. Taken out at Livingston the canal would encounter no difficult construction, and would chiefly consist in earth excavation with very little rock work. It would require a few fills and flumes in crossing the larger side streams, such as the Little and Big Timber, Otter and Sweet Grass Creeks. It would reach the summit somewhere north of Merrill at an altitude of about 4,400 feet and thence could be conducted with an easy alignment eastward, with occasional falls to loose grade.

The water flowing in the Yellowstone River at Livingstone during the irrigating season this year averaged 2,300 cubic feet per second, which, with an allowance of thirty per cent. for loss by seepage and evaporation in the canal, would leave about 1,600 second feet at the point of utilization or sufficient to irrigate 160,000 acres.

The average normal discharge from Yellowstone Lake is 700 second feet, and a dam about 300 feet long and less than ten feet high, constructed below the outlet of the lake, would store the outflow from October to May, inclusive, eight months, a total including flood discharges of at least 600,000 acre feet, an amount which, allowing for loss by evaporation in the lake, and by seepage and evaporation in the canal, would irrigate 425,000 acres, in addition to the 160,000 acres previously mentioned. Besides this volume probably half as much more can be readily stored on the Lamar and Gardner Rivers, and the other branches of the Yellowstone which join it above Livingston, bringing the total area of reclaimed land to nearly 1,000,000 acres.

There are many similar and even better opportunities for irrigation development, such as the construction of a canal from the West Gallatin River near Bozeman. This canal would require no expensive diversion line, as its waters would become immediately available at the headworks, and by appropriating the 500 second feet of water flowing in the river, would reclaim at a minimum cost 50,000 acres, or twice the amount of land now cultivated there. Storage on the Upper Gallatin River would greatly increase the amount of reclaimed land.

Storage reservoirs can be easily constructed on the headwaters of the Beaver Head River, whereby at least 150,000 acres could be added to the 25,000 acres now under cultivation in the Beaver Head Valley near Dillon.

A canal requiring no diversion line can be taken out on the east side of the Missouri River near Toston, which will irrigate all of the good land in the Missouri Valley, at least 100,000 acres, This canal would require some fills and aqueducts in crossing the various side steams such as Deep and Duck Creeks, and Confederate Gulch.

Detailed surveys have been made during the past summer on the Sun River which indicate that storage will add some 250,000 acre feet to the amount of water in that stream now available for irrigation. There are at least 600,000 acres of good agricultural land between the Dearborn, Sun, and Teton Rivers, which must forever remain barren of cultivated products unless provided with water by means of storage on these streams, and the surveys above alluded to indicate that by this means 160,000 acres of this land can be reclaimed by the Sun River alone.

Mention might be made to many more similar projects, such as the construction of a simple canal from the Missouri River to irrigate Chestnut Valley, south of Great Falls, whereby 120,000 acres would be reclaimed; or one from the Upper Madison River whereby 230,000 acres of the Madison Valley might receive water, but the foregoing will suffice to show the possibilities of irrigation development in Montana.

It would be doing the resources of a great and vast area of Montana injustice if reference were not made to the Milk River country, the great Indian reservation of 17,680,000 acres in the northern part of the State which has recently been open to settlement. This region has not been examined by the author, but from conversations with a number of its well-informed inhab-

itants it appear that the soil is very fertile, and that during average moist years excellent crops can be raised there without irrigation. This last statement, however, should not be too readily accepted. It is probable that some storage water may be retained in the hills along the British line, though its development will doubtless involve international questions.

A Glance at the Future.

This interesting subject cannot be passed by without a little castle building, and accordingly an attempt will be made to show what the future of Montana may owe to irrigation.

It has just been shown how and where 1,750,000 acres may be added to the area at present under cultivation ; many times this amount, however, can be reclaimed. Settled as closely as a large irrigated district would naturally be, these 1,750,000 acres will be increased by about 15 per cent. or 262,500 acres, the area which will be occupied by roads, buildings, and towns ; that is to say over 2,000,000 acres will be rendered capable of sustaining the highest degree of settlement, though in reality this amount will be much greater since a large portion of the land will not be directly irrigated, since it will indirectly receive sufficient moisture from the neighboring fields to render it serviceable for pasturage.

It has been claimed by various authorities that a homestead of forty acres is abundant for the support of a family, assuming this estimate to be correct, then 2,000,000 acres will support 50,000 families ; at five persons each this would give a farm population of 250,000. This number of farm workers would require a town and village population of one and one-half more, or our 2,000,000 acres would add in all 375,000 people to the State.

On the same basis the 18,000,000 acres which have been classified as irrigable land, (and this estimate is below that of the Montana Society of civil engineers and other authorities), would support 3,120,000 inhabitants.